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# BULLETIN

OF THE

## SCIENTIFIC LABORATORIES

OF

### DENISON UNIVERSITY



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# BULLETIN

## OF THE

### SCIENTIFIC LABORATORIES

#### OF

### DENISON UNIVERSITY

Edited by  
**KIRTLEY F. MATHER**  
 Permanent Secretary, Denison Scientific Association,  
 Granville, Ohio

The entire file of volumes 1 to 13 was destroyed by fire; no publications issued prior to 1907 are now available. Volumes 14 to date may be obtained from the editor at \$2.00 per volume, with the exception of volume 15, the price of which is \$1.00. Separate parts, as listed below, may be purchased at the prices indicated.

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## FOREWORD

THE BULLETIN OF THE SCIENTIFIC LABORATORIES was established in 1885 by C. L. Herrick, who at that time filled the chair of "Geology and Natural History" at Denison. Two years later it became the official organ of the Denison Scientific Association, and has since been edited by the "Permanent Secretary" of that organization, a position occupied by various members of the science staff. The funds to support the publication have been provided by the Trustees of Denison in recognition of the fact that it is the province of the University not only to dispense information, but to enrich the store of human knowledge by original research and independent investigation. The pages of THE BULLETIN are open to contributions from the members and past-members of the Denison Scientific Association; articles submitted for publication will be welcomed by the editor at any time.

It is appropriate in this connection to acknowledge the indebtedness of the University and the Scientific Association to Dr. Frank Carney, formerly Professor of Geology, who was editor of THE BULLETIN from 1908 to 1917. Volumes 14 to 18, inclusive, were issued under his direction; they include more than half the total number of pages published since 1885. His editorial ability and facile pen did much to establish THE BULLETIN on a high plane of scientific excellence and to bring it the recognition in the realm of science, both in America and abroad, which it now enjoys.

CLARK W. CHAMBERLAIN.



## ECHINODERMATA OF THE BRASSFIELD (SILURIAN) FORMATION OF OHIO

AUG. F. FOERSTE

Relatively few echinoderms from the Upper or Albion division of the Medinan Silurian have hitherto been described. From the Cataract strata of Ontario, *Brockocystis clintonensis* (Parks), *Brockocystis huronensis* (Billings), *Brockocystis tecumseth* (Billings), *Mesopalaeaster* (?) *cataractensis* Schuchert, and *Mesopalaeaster granti* (Spencer) are known. From the Girardeau of Missouri and Illinois, *Cyclocystoides illinoisensis* Miller and Gurley, *Glyptocrinus* (?) *fimbriatus* Shumard, and *Ptychocrinus splendens* (Miller) have been described. *Deltacrinus alleni* (Rowley), *Gissocrinus* (?) *problematicus* Rowley, *Glyptocrinus inseparatus*, with its varieties *carinatus* and *pentagonus*, all by Rowley, have been described from the Edgewood of Missouri and Illinois.

Although the Brassfield formation of Ohio, Indiana, and Kentucky contains almost everywhere a considerable quantity of coarsely crinoidal material, only one species, *Clidochirus americanus* Springer, has been listed by Bassler from this formation; even this species, so far, has not been published.

This extreme poverty of echinoderm material from the Brassfield formation may be easily understood on studying the lithology of the rock. Where the echinoderm material is most abundant the rock gives evidence of having been deposited by strong and irregular currents. Cross-bedding is common. The fragmental material is more or less rounded. Dismembered plates and columnals of crinoids are common, fragments of columns an inch or more in length are not infrequent, but rarely are enough plates of the same calyx still found in their original relative position to make possible even a generic identification. The material described on the following pages represents all

the writer ever found which is worthy of any attention. A close discrimination of the calyx plates and of the fragments of columns suggests that the Brassfield sea contained an abundance of crinoidal life, representing many species. The trouble is not with the lack of abundance, but with the dismembered condition of this material.

Under the term crinoidal material, fragments of cystids frequently are included. Pectinirrhombs, such as exist among the Glyptocystidae, occur in considerable numbers at some localities. Starfish material is extremely rare. In a dismembered condition it probably could not be recognized as such.

Fragments of calyces with a number of plates still in position occur occasionally in the soft blue clay forming the top of the Brassfield formation at the quarry northwest of the railroad station at Centerville, and at the equivalent horizon in the abandoned quarry at the Soldiers Home, west of Dayton, Ohio. In the area southeast of Byron, about 8 miles northwest of Xenia, Ohio, the weathered top of the Brassfield limestone not infrequently retains the basal portions of crinoid calyces, but usually poorly preserved. Unfortunately the exposed rock surface is relatively small; otherwise this area might give promise of more crinoid material.

In the southern part of Ohio, in Highland and Adams counties, *Brockocystis nodosarius* is represented by numerous fragments in the lower third of the Brassfield formation; fairly preserved thecae, however, were found only at one locality, about two miles west of Peebles. Two of the starfish described from this part of the state, on the following pages, were obtained near the top of this *Brockocystis* zone.

In addition to the material from the Brassfield, there is described on the following pages *Clidochirus ulrichi*, the only crinoid found so far in the Dayton limestone. This limestone lies immediately above the Brassfield formation and is correlated with the *Pentamerus* limestone in the lower part of the Clinton formation of New York. A poorly preserved specimen of *Botryocrinus*, from the *Holophragma* zone at the top of the Upper or Lilley member of the West Union formation at Hillsboro,

Ohio, also has been added. This upper member of the West Union formation is distinct faunally from the Lower or Bisher member. The latter is correlated provisionally with the Iron-dequoit member of the Clinton of New York, so that the upper member may correspond to the lower part of the Lockport formation of that state. The so-called Niagara shales of the earlier reports of the Ohio Geological Survey, known as the Crab Orchard shales in Kentucky, contain, in their upper layers, a fauna including some of the characteristic species of the typical Clinton of the central and more eastern parts of New York, such as *Liocalymene clintoni*.

Several of the specimens here discussed present very unusual features. The nodose aggregation of columnals at the top of the stem of *Brockocystis nodosarius* is one of these. The frequent coiling of the stem of an unknown crinoid, (plate I, fig. 6), with the narrow end of the stem at the center, is another. An ancestral form of *Myelodactylus* is a third. On plate II (fig. 6) are figured fragments of a crinoid which would be a *Dimerocrinid* if it had sub-basal plates; but the latter apparently do not occur. On plate VII are presented several figures of an echinoderm (*Stereaster*) regarding which little is known at present beyond the fact that it resembles a star-fish in appearance but not in structure. It promises to be one of the anomalous forms of which the relationship remains unknown, at least for the present. Finally, on plates IV and V is figured a star-fish which evidently diverges distinctly from typical forms of *Mesopalaeaster*.

***Brockocystis nodosarius* sp. nov.**

*Plate I, figs. 1, 2, 3, 4, 5*

Theca small, oblong in outline, 11 or 12 mm. long and 9 or 10 mm. wide. Pectinirhombs present on plates 1-5, 12-18, 14-15, and 10-15, but absent on plates 11-17; more or less discrete along the suture which separates the two plates forming each rhomb. The lower boundary of the pectinirhombs is more strongly defined on plates 1 and 12 than is the corresponding upper boundary of the same pectinirhombs on plates 5 and 18.

The number of stereom-folds in pectinirhomb 1-5 is 3 or 4; in pectinirhomb 12-18, about 5 or 6; in pectinirhomb 14-15, about 7 or 8; and in pectinirhomb 10-15, about 4 or 5.

Prominent protuberances occupy the middle of all the plates belonging to the first three rows. The protuberances of the four basal plates project downward, beyond the top of the column, for distances approaching or equalling one millimeter. Where pectinirhombs are present, the latter encroach on the central protuberances, and similar encroachment is noticed also in case of the plates bordering on the anal area; the encroachment is least in case of plate 7. In some specimens, low ridges connect the protuberances of adjacent plates; in others they are absent. In their present state of preservation the plates appear smooth. Anal area apparently elliptical in form, about 3 mm. in height and 2 mm. in width. None of the plates belonging to this area are preserved in the specimens at hand.

Only traces of the food-groove system remain. The ambulacra recline on the surface of the theca as in other *Lepadocystinae*. In one specimen, one of the ambulacra passes along the upper left margin of plate 17 to within one millimeter of the top angle of plate 11; another ambulacrum reaches the upper part of plate 18, but does not extend nearer than one millimeter to the upper margin of that part of the pectinirhomb which is present on this plate. In the same manner, ambulacra reach only the top of plates 19 and 15. This is true presumably also in case of plate 16, although this plate is not exposed in any specimen at hand. There scarcely is room for more than two or three brachioles on each side of each ambulacrum. These brachioles are at least 5 mm. long, and are directed upward. They are biserial dorsally, the plates of the two series alternating. The length of these dorsal plates equals or only slightly exceeds their width. The ventral side of the brachioles is not exposed in any specimen at hand but its probable appearance may be inferred from the corresponding parts of *Lepadocystis moorei*, Meek, a closely related species occurring in the upper part of the Richmond group, at Richmond, Indiana. In the latter species the covering plates on the brachioles are more numerous than the dorsal plates; in

outline they are long and linear, with their longer axes directed at right angles to the length of the brachiole. The ambulacral plates which remain attached to the theca of the species of *Brockocystis* here under discussion appear to be of comparatively large size and are relatively few in number.

The semilunate pore (gonopore) on plate 23 is distinctly defined in the angle between the two ambulacra which extend toward plates 17 and 18. A more minute pore (hydropore) may be present directly beneath the center of the semilunate pore, but is not distinctly defined. Plate 23 may be a double plate; at least, a crack appears to pass through the center of the semilunate pore.

The largest fragment of a column remaining attached to any theca known is 20 mm. in length. In the more distal parts of the column, for a length of 12 mm., the column is narrow, ranging from two-thirds to a whole millimeter in width, the proximal columnals being broader. In the proximal part of the column, 8 mm. in length, the columnals are collected into two groups, of which the first is inversely pyriform, and the second is inversely truncate-conical in form. The constituent columnals of each group are anchylosed together, but the groups separate readily from each other and from the remainder of the column. In this separated condition the groups form characteristic fossil remains easily identifiable generically, even in the absence of the theca. This is true especially of the inversely pyriform groups. A vertical section of one of these groups (fig. 5) shows a lumen from three-fourths of a millimeter to a whole millimeter in width. Along this lumen, the constrictions locating the inner parts of the columnals appear equally spaced, six columnals occupying a length of slightly more than 3 mm. Exteriorly, the marginal parts of the constituent columnals of the inversely pyriform groups rise, so that externally the lower three or four columnals of each group appear distinctly longer than the upper three or four columnals of the same group. The topmost columnal is constricted in size to the width of the lowest columnal, and is hidden in the base of the large depression indenting the top of the group. To this hidden columnal is attached the second

group of columnals, of which six columnals occupy a length of about 2.3 mm. This second group also has a deep, wide depression at the top, as though the inner part of the body-cavity of the tegmen were connected directly with the lumen. The upper margin of this second group is overlapped by the descending extensions of the protuberances on the basal plates of the theca. If the proximal columnals are the youngest, then the second group may be due merely to a rejuvenation of the process which gave rise to the first group. When the upper margin of the first group had attained such a size that it crowded upon the overlapping extensions of the basal thecal plates, a new series of smaller columnal plates appears to have been started. It is conceivable that stereom was added to the exterior of the columnals after the more central parts already had been formed.

In the figured specimens, the surface of the thecal plates appears to be smooth; however, on many of the loose thecal plates, evidently belonging to the same genus, the surface of the plates is covered by a reticulated series of lines, similar to that shown by *Brockocystis tecumsethi* (Billings) (plate III, fig. 1) from the top of the Manitoulin dolomite, on Manitoulin island, in Ontario, Canada. It is possible that there are two species of *Brockocystis* in the Brassfield strata of Ohio, but if that be true, this fact has not yet been definitely determined.

*Locality and position.* The specimens here figured were obtained in the lower part of the Brassfield formation, beneath a trestle along the railroad about two miles west of Peebles, Ohio. They were in the upper part of the cherty layers which occur a short distance above the base of the Brassfield formation in the southern part of the state. The following section is exposed beneath the trestle, in descending order:

	<i>feet.</i>
Limestone, cherty nodules few.....	3
Limestone, in more massive beds, cherty nodules large and numerous. 3	3
Limestone, thinner bedded, cherty nodules small and few.....	2
Limestone, thin-bedded, no chert noticed.....	2.5
Creek level beneath tressle.	

The following fossils were secured here, chiefly from the upper half of strata here listed, which belong to the more cherty part

of the section: *Cyathophyllum facetum*, *Brockocystis nodosarius*, *Hemitrypa ulrichi*, *Phaenopora multifida*, *Rhinopora verrucosa*, *Hebertella daytonensis*, *Hebertella fausta*, *Orthis flabellites*, *Platystrophia daytonensis*, *Leptaena rhomboidalis*, *Plectambonites transversalis*, *Strophonella daytonensis*, *Illaenus ambiguus*, and *Phacops pulchellus*.

At the quarry directly north of Lawshe, Ohio, the strata equivalent to the cherty limestones listed above are underlaid by several thinner bedded limestone layers containing *Platymerella manniensis* Foerste (Bull. Sci. Lab. Denison Univ., vol. 14, 1909, p. 70, pl. 1, figs. 1 A-D) and *Plectambonites transversalis*. So far, this is the only locality known in Ohio, Indiana, or Kentucky, at which *Platymerella* occurs.

The geographical range of *Brockocystis nodosarius* is limited to the southern part of Ohio. No specimens have been found so far in the neighboring parts of Kentucky. It occurs at numerous localities in Adams and Highland counties, in Ohio, and has been found also at Sharpsville, in the southern angle of Clinton county. The most western locality at which it has been noted is the quarry in the creek bottom, a short distance east of Danville. Eastward, its range appears limited only by the extent of the outcrops.

### An unknown Brassfield Lepadocystid

#### Plate II, fig. 2

Detached plates of some Lepadocystid are common within 5 feet of the top of the Brassfield formation at the exposure along the electric railroad where it follows the Dayton and Troy pike, about a mile northwest of Cowlesville, in the southern part of Miami County. Many of these plates bear pectinirhombs, and occasionally one of them bears the double pectinirhomb characteristic of plate 15 in the genera *Brockocystis* and *Lepadocystis*. In some of the plates the halves of the pectinirhombs are broad but of small height; they lie near the margin of the plates; the inner margin of the pectinirhomb is gently concave, the outer margin consists of two sides meeting at a very obtuse angle at

the middle; both the outer and inner margins are delimited by a narrow linear elevation. On other plates the halves of the pectinirhombs lie farther from the margins of the plates, and the outer margin as well as the inner margin of the pectinirhomb is more lunate in outline. There is no evidence of central nodose elevations on any of these plates, nor of any prominent radiating sculpture.

The associated columns are circular in cross-section, with a circular lumen. The columnals are of very short height, 15 occurring in a length of 5 mm. in a column 6 mm. in diameter. The ends of these columnals are finely and radiately striated. There is no tendency toward the grouping of these columnals into more or less nodose or pyriform sections.

Both the dissociated plates and the associated columns probably belong to some undescribed species from among the Lepadocystinae, possibly to *Brockocystis*.

Similar plates and columns occur at the same horizon at various localities in the southern part of Miami and Clark counties and in the northern halves of Miami and Greene counties. No attempt has been made to determine their area of distribution. They are described here chiefly to call attention to the presence of additional cystids in the Brassfield formation in the hope that more perfect specimens may be found.

### Coiled "crinoid" stem

*Plate I, fig. 6; plate II, figs. 5 A-C*

1884, American Naturalist, p. 57

A coiled column of some echinoderm, obtained in the upper part of the Brassfield limestone in the Soldiers Home quarry, west of Dayton, Ohio, was figured by the writer thirty-five years ago. This column was at least 11.5 cm. long, but, on the supposition that almost all of the second largest volution is missing, an original length of at least 21 cm. is probable. This column increased from a diameter of 1.5 mm., at the smaller end of the column, to a diameter of 6.5 mm. in a length of 7.7 cm. Beyond

this point, the volutions were not preserved continuously. The columnals were approximately circular, with a moderately irregular margin.

A second coiled column, (plate I, fig. 6) evidently belonging to the same species, was found recently, also in the upper part of the Brassfield limestone, 1 mile northeast of Wilberforce, and  $4\frac{1}{2}$  miles northeast of Xenia, Ohio. The exposure occurs east of the road to Clifton, on the northern side of the road to the Eastpoint school, along the upper part of the creek bed. Here large dissociated columnals of the same species are very common in the ferruginous layer,  $2\frac{1}{2}$  feet below the base of the Dayton limestone. The coiled column found here has a length of 16.4 cm. About three and a third volutions are preserved. Measuring from the larger toward the smaller end, the first volution has a length of 9.1 cm.; the second, of 5 cm.; the third, of 1.8 cm.; and the remainder, of 0.5 cm. At the larger extremity the columnals have a diameter of 8 mm.; at a distance of 7.8 cm. from the larger end this diameter is 6.5 mm.; 7.7 cm. from the second point the diameter equals 2.7 mm.; at its smallest extremity the diameter is only slightly more than 1.5 mm. These measurements suggest that the rate of decrease in the diameter of the column is more rapid nearer the smaller extremity. The margins of the columnals are badly weather worn but apparently were approximately circular, with a moderately irregular margin.

The columnals are not of equal thickness. This is more readily noticeable in the larger columnals. Frequently narrower and thinner columnals alternate with thicker ones in such a manner as to suggest intercalation subsequent to the development of the larger columnals. This is a familiar feature among various genera of crinoids. Since both the larger and the intercalated smaller columnals become thinner toward the lumen, it is evident that articulation is secured by still smaller columnals, not readily seen in a view of the exterior of the complete column, though frequently still attached to the disarticulated larger columnals. The articulating surface of these articulating columnals, and the corresponding surface of that part of the larger columnals which surrounds the lumen, is radiately striated.

Similar coiled crinoid stems, evidently belonging to the same species, have been found recently also at the large quarry northwest of the railroad station, at Centreville, Ohio.

Disjointed columnals (plate II, figs. 5 A-C) are very common near the top of the Brassfield limestone, both in Ohio and in eastern Kentucky. The maximum size attained by these columnals is 25 mm. Most of them do not exceed 15 mm. in width. Columnals between 15 and 25 mm. in width usually are almost circular in outline with little evidence of crenulation. Smaller columnals frequently are crenulated; some of the smaller specimens are pentagonally lobed; when they are both lobed and crenulate they frequently are very pretty and attract attention as beads. In both of the coiled columns found so far the outlines of the columnals are moderately crenulated but not pentagonal in outline. Whether the more or less pentagonal columnals represent a different species is unknown at present. On many of these columnals it is possible to recognize five equally distant, radiating, narrow color lines suggesting former sutures, and indicating the pentamerid origin of the columnals.

The radiating striae on the articulating surface of the articulating columnals, described above, number 10 or 11 in a distance of 1 mm. They correspond closely in appearance with the striae on the articulating surfaces at the base of the calyces of the two species of crinoids described next. Both of these species occur at the top of the Brassfield formation in the area southeast of Byron, about 7 miles northwest of Xenia, Ohio. Both are found at about the same horizon as the coiled stem described from the top of the Brassfield limestone, 1 mile northeast of Wilberforce. Both are very similar in the size and the outline of the first three circles of plates, and apparently even in the degree of development of the very low but broad radiating ridges ornamenting the plates. They differ chiefly, as far as the calyces are known at present, in the shape of one of the plates in the first or basal circle. In the first species here described, (plate II, figs. 6 A-E) the top of one of the basal plates is truncated, indicating the position of the anal side of the calyx. In the second species all of the plates belonging to the first circle

are pentagonal in form, and there is no indication of the anal side in the part of the calyx known at present. Moreover, in the second species, (plate VI, figs. 2 A-D) the surface ornamentation consists of numerous parallel lines which are perpendicular to the adjacent sides. The surface of the first species appears to have been relatively smooth.

At present there is no means of determining whether the coiled crinoid stems described here belong to either of these two species, but the latter are the only forms known of such size as to suggest the possibility of such a relationship.

***Dimerocrinus* (?) *vagans* sp. nov.**

*Plate II, figs. 6 A-E*

Basals five, four of them pentagonal in outline, the fifth truncated and supporting the anal x plate. The inner margin of the circle of five basals is formed by the aperture connecting the lumen of the stem with the body-cavity of the calyx. The articulating surface for the attachment of the column is formed by a circular ridge which encloses the proximal parts of the five basals. The area thus enclosed is deeply concave. The crest of the circular ridge traversing the basals is marked by numerous, very fine, short lines arranged as though radiating from the center of the circle. About 9 or 10 of these lines occur in a width of 1 mm. No infrabasals are present in any of the specimens found. In the specimen represented by figure 6A the margin of the articulating surface appears to be slightly scalloped, somewhat as in figure 6D. If this could be confirmed by well preserved specimens it would indicate the former presence of infrabasals. The presence of such infrabasals would relegate our specimens to the *Dimerocrinidae*. As a matter of fact, however, the former presence of infrabasals remains extremely doubtful, in which case the calyces here described would not fit into any of the families of *Crinoidea* as now defined. Figure 6D is intended to indicate the possible relationship of these calyces to the *Dimerocrinidae*.

Judging from the fragments at hand, the basal part of the calyx must have been comparatively flat as far outward as the distal parts of the first interradians. Beyond the latter, the sides of the calyx probably curved more or less rapidly upward, producing a semi-globose form, flattened beneath, possibly similar to that of *Lyriocrinus*. The lateral diameter of the calyx must have equalled at least 60 mm. Obscure lines of elevation traverse the plates somewhat as indicated in figure 6E.

*Locality and position.* Within  $2\frac{1}{2}$  feet from the top of the Brassfield limestone, 7 miles northwest of Xenia, Ohio. The locality may be reached by going 1 mile east from Byron, then 1 mile south, to a shallow wet-weather stream exposure, on the east side of the pike.

### Base of calyx of unknown species of crinoid

#### *Plate VI, figs. 2 A-D*

At the same locality and horizon as the preceding species, southeast of Byron, Ohio, occur the basal parts of the calyces of a second species of crinoid, closely resembling the preceding species in general appearance. The chief difference consists in the fact that there is no differentiation of the anal side among the basals, nor, apparently, among the radials and first interradians, as far as the latter are preserved. All of the basals are pentagonal in outline. The articulating surface for the attachment of the column is similar to that of the preceding species. If infrabasals ever were present, this fact remains to be proved. The plates of the calyx are ornamented by close-set parallel striae arranged in groups which are perpendicular to the adjacent suture lines. In intermediate parts of the plates these striae tend to break up into series of granules which are elongated more or less in the direction of the neighboring striae. The general form of the calyx probably was similar to that of *Lyriocrinus melissa* Hall.

This second species appears so closely similar to the preceding species here described, as far as preserved, that there is a possibility of both belonging to the same family of crinoids. All the Dimero-

crinidae, however, have an anal plate following a truncated basal. In the present state of our knowledge of these calyces any attempt to assign them to some definite family of crinoids would be merely guesswork. The chief reason for calling attention to them is the fact that this and the preceding species possibly may belong to the interesting coiled crinoid stems described earlier in this paper. They are of sufficient size, have a large enough lumen, the surface markings on the area of attachment are similar, the specimens occur at the same horizon, and in sufficient numbers at least to suggest a possible former connection.

Figure 41 on plate VIII of vol. 3, Bull. Sci. Lab. Denison University, probably represents another specimen of the same species as that here described. This figure is reprinted on plate 27 of vol. 7 of the Ohio Geological Survey, published in 1895. The specimen was obtained at Reed's hill, east of Fairfield, Ohio.

**Clidochirus** sp.

*Plate VII, fig. 1*

Species named by Springer in his Monograph of the Crinoidea Flexibilia, now in press.

Infrabasals low, not exceeding 1 mm. in height, presumably three although the complete circuit is not preserved in the specimen at hand; exposed surface erect, taking part in the calyx wall and having about the same slope as that of the basals. The right posterior infrabasal is broadly triangulate above. The anterior and right anterior infrabasals are merged into a single plate with a gently concave upper surface, bearing the right anterior basal. Although the left anterior and left posterior basals are only imperfectly preserved, it is assumed that these plates also are merged into a single plate with a gently concave upper margin, bearing the left posterior basal. The height of the basals only slightly exceeds their width, excepting in the case of the posterior basal which is a little higher and bears the anal x plate on its upper right margin. This anal x plate is in contact with the upper left margin of the radial at the base of

the right posterior arm, and also with the left side of the first costal and the lower left side of the second costal belonging to the same arm; on the other side, this anal x plate is in contact with the right side of the radial and the lower right side of the first costal belonging to the left posterior arm. Each arm begins with the radial followed by two costals, except in the case of the right posterior arm where the presence of the "radianal in its primitive position under the right posterior radial, resting on the basals" (Springer) produces the appearance of a radial followed by three costals. The distichals in each arm-branch number four, excepting in the case of the left branch of the left posterior arm, where only three distichals occur. Most of the subsequent branches expose six palmars, but the tips are in-folded and are not well exposed so that the number of palmars may equal seven or eight, or even may exceed that number. The arms all are closely adjoined laterally.

*Locality and position.* In the clayey layers at the top of the Brassfield formation, in the large quarry half a mile northeast of the village of Centerville, Ohio.

*Remarks.* This species is characterized by its elongate form. The sides of the calyx diverge at an angle of about 40 degrees as far as the axillary costals. The series of distichals are more nearly vertical, and, beyond the distichals, the series of palmars are incurved. The ratio of the length to the width of the entire crown is about 17 to 10.

Figure 39 on plate 8, vol. 3, Bull. Sci. Lab. Denison University, republished on plate 27 of vol. 7 of the Ohio Geological Survey in 1895, represents a specimen obtained in the soft clay at the top of the Brassfield formation, at the Centerville quarry. In the original publication it was described as *Ichthyocrinus* sp.; a fragment of the calyx. This reference to *Ichthyocrinus* is based solely upon the close lateral abutting of the arms, and the general aspect of the fragment. At the base of the fragment is an axillary costal, followed by two arm-branches, each with three distichals; this is followed by four arm-branches, the two median ones with five palmars, the right-hand branch with eleven palmars; beyond the palmars, branching takes place

again. A part of another arm forms the right side of the fragment; the distichals of the left branch are followed by two arm branches, of which the left one has nine palmars, and the right one has five palmars. In the case of each arm, the two median arm branches following the distichals are broader and shorter; the two exterior arm branches of the same set are narrower and longer, recalling in this respect *Clidochirus* of which it may be another species.

***Clidochirus ulrichi* sp. nov.**

*Plate II, figs. 1 A, B; text figure 1*

Infrabasals three, 1.3 mm. in height, exposed surface sloping at the same angle as the basals. Basals, 2.5 mm. in height. Radials, except in the case of the right posterior arm, 2 mm. in height. Radials, except in the case of the right posterior arm, followed by two costals, of which the first has a height of 1.7 mm. while the second or axillary costal has a height of about 2 mm. at its middle. The right posterior arm appears to consist of a radial followed by three costals, and the designations first, second, and third or axillary costal are used in connection with this arm in the immediately following parts of this description. The radianal is relatively long and narrow, narrowing especially toward the base; it lines the left margin of the radial at the base of the right posterior arm for its entire length and borders also on the lower left margin of the first costal of this arm. The anal x plate borders on the lower left margin of the second costal and lines the left margin of the first costal of the right posterior arm; on its left side it barely reaches the lower right corner of the second or axillary costal, but borders on the right side of both the first costal and the radial. In all arms there are four distichals in each vertical series. Each arm terminates with four series of palmars, of which, in the specimen at hand, the two outer series consist of about eleven or twelve palmars, while the two inner series appear to be shorter and to consist of only eight or nine palmars.

Column slender, about 1.8 mm. in width. Columnals varying between 0.4 and 0.5 mm. in length, frequently alternating with much shorter intercalated columnals.

*Locality and position.* In the upper part of the Dayton limestone, at the base of the Niagaran division of the Silurian, along the side of the Germantown pike, southeast of the Soldiers Home, west of Dayton, Ohio. Named in honor of E. O. Ulrich, whose

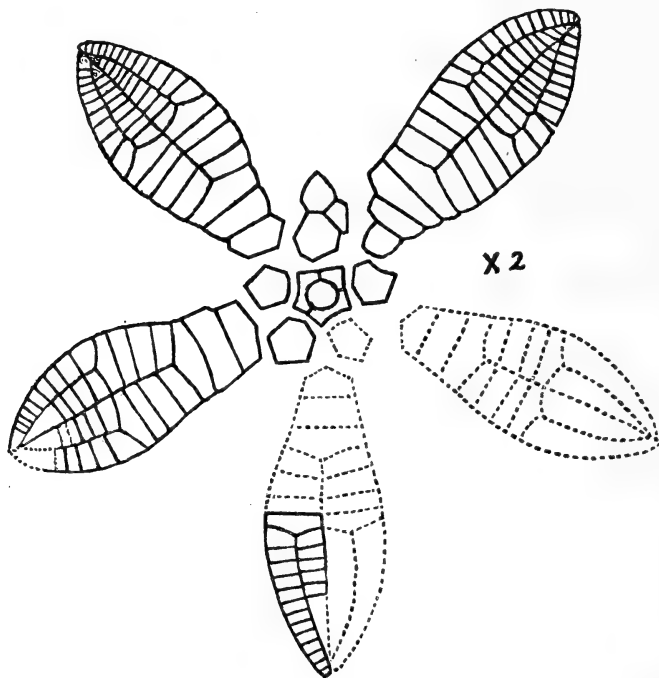


FIG. 1. CLIDOCHIRUS ULRICHI SP. NOV. DIAGRAM OF PLATES, WITH ANAL SIDE AT TOP

investigations have enriched every department of Palaeozoic Paleontology.

*Remarks.* If, in accordance with the investigation of Springer, the lowest plate in the right posterior arm series be interpreted as the "radial in its primitive position under the right posterior radial," then the first costal of the preceding description becomes the radial, and the right posterior arm is credited with only two,

in place of three costals. In that case it is evident that the specimen here described has two radianal plates, the primitive radianal plate at the base of the right posterior arm and the secondary radianal plate wedged in between the primitive radianal and the anal x plates. It is not known to what extent this secondary radianal plate will be found to be a constant feature in this species.

Compared with the Brassfield species of *Clidochirus* described and figured by Springer, and also described in this paper, the crown of *Clidochirus ulrichi* is elliptical ovate rather than inversely conical in form. The sides of the calyx are more divergent and the greatest width of the crown is near mid-length. All of the arm plates are relatively shorter and wider, especially in case of the costals and distichals.

### **Myelodactylus (Eomyelodactylus) rotundatus**

sub-gen. et sp. nov.

*Plate I, fig. 8; plate II, fig. 3*

Fragment of column, coiled, about 115 mm. in length, broken off where the reversal of curvature begins, possibly within 25 mm. of the base of the crown. The greater diameter of the stem, measured from the convex to the concave side of its curvature, equals 2.25 mm. throughout almost the entire length of the fragment, but at a distance of 5 mm. from the beginning of its reversal in curvature this diameter diminishes rapidly and is reduced to 1.4 mm. at the broken end. It probably continued to diminish in size gradually toward the crown. The diameter at right angles to the one just discussed is a little less, thus producing a slightly elliptical cross-section.

The length of the columnals varies. The first three columnals at the broken end, where reversal begins, occupy a length of 1.5 mm.; the next three, 1.9 mm.; the next three, 2.0 mm.; the next three, 2.3 mm.; then the length of the columnals remains constant until a point opposite the broken end has been reached. Then the length diminishes to three columnals in 1.8 mm., remains

constant for about one-third of a volution, and diminishes to three columnals in 1.5 mm. at the end of the last third of a volution.

Throughout by far the greater part of the length of the column the latter has been split in two along a plane parallel to the plane of curvature. This exposes a darkened line, never more than three-tenths of a millimeter in width, which evidently locates the lumen. The latter is distinctly nearer the convex side of the curvature of the column, and, in transverse sections of the stem, is seen to be wider in a direction at right angles to the plane of curvature. Under a lens it appears possible to detect four additional planes, indicated by slightly darker coloring, suggesting original pentamerism (plate II, fig. 3) with the unpaired segment on the convex side of curvature of the column. Why this unpaired segment should split so smoothly along its middle is unknown, but the immediately opposite suture evidently is the one along which the stem should split most readily.

There is no conclusive evidence of the presence of two rows of cirri, nor of points of attachment for the latter, although vague traces of short cirri appear to be present at one point.

*Locality and position.* Holotype found up stream from Silver Springs, on the head waters of Caesars Creek,  $4\frac{3}{4}$  miles south-east of Xenia, Ohio. The locality is over a mile and a half up stream from the Xenia-Wilmington pike. Here it occurs in the upper half of the Brassfield limestone, associated with the following fauna: *Cyathophyllum facetus*, *Halysites catenularia*, *Hemitrypa ulrichi*, *Chasmatopora angulata*, *Clathropora frondosa clintonensis*, *Phaenopora expansa*, *Ptilodictya expansa*, *Ptilodictya americana*, *Pachydictya bifurcata*, *Pachydictya obesa*, *Rhinopora verrucosa*, *Rhipidomella hybrida*, *Platystrophia daytonensis*, *Leptaena rhomboidalis*, *Brachyprion* moderately convex, *Strophonella daytonensis*, *Strophonella hanoverensis*, *Atrypa marginalis*, *Cyclonema daytonense*, *Illaenus ambiguus*, *Illaenus daytonensis*, *Proetus determinatus*, and *Encrinurus thresheri*.

*Remarks.* The reversal of curvature at the broken end of this column is indicated by the distinctly greater length of the last three columnals along the inner side of the coil. This suggests

the reference of the column to *Myelodactylus* or *Herpetocrinus*, two terms regarded at present as applying to the same genus. In hitherto described species of this genus the column is distinctly concave longitudinally along the inner side of curvature of that part of the column which bears the two rows of cirri. In the Brassfield species here described there is no trace of such a concave indenting of the outline of the columnals along the inner curvature of the column, and, hence, the Brassfield specimen is regarded as representing an earlier stage of development than typical *Myelodactylus*, and the subgeneric term *Eomyelodactylus* is here proposed with this Brassfield specimen as a type. In American strata, *Myelodactylus* is not known in strata earlier than the Rochester shale of New York and the Laurel limestone of Indiana, another species being known from the Waldron of Indiana, and a fourth from the Racine of Bridgeport, Illinois.

***Botryocrinus* sp.**

*Plate II, figs. 4 A, B*

Calyx imperfect, more or less distorted by obliquely vertical compression, and with only parts of the upper margin of several of the infrabasals preserved. Basals, radials, radianal, and anal x plates similar in outline and general form to *Botryocrinus polyxo* Hall, from the Waldron shale of Indiana, but the latter attains a much larger size, and the facets for the reception of the arms are more vertically inclined. The maximum width of the calyx here described is about 13 mm. Although probably representing a new species, not enough remains of the specimen at hand to reveal any distinguishing characteristics.

*Locality and position.* In the *Holophragma* zone at the top of the Upper or Lilley division of the West Union formation, in the Zink or Corporation quarry, in the eastern part of Hillsboro, Ohio.

**Mesopalaeaster (Hemipalaeaster) schucherti** sp. nov.*Plates IV, V*

Measurements: disk imperfectly preserved; its radius, measured from the center to the nearest part of the interbrachial arc, estimated as between 10 and 12.5 mm. Length of rays, measured from the basal radial to the tip, 25 mm.; distance from center of disk to tip of rays estimated as between 34 and 36.5 mm. Ratio of the longer radius, from the center of the disk to the tip of the rays, compared with the shorter radius, to the nearest part of the interbrachial arc, between 3.4 and 3, probably nearer the latter.

Abactinally, the disk is limited by an interrupted circle of large plates, consisting of the basal supramarginals (*S*, in figure on plate V), the dorsal interradians (*i*), and five plates (*r*), one at the base of each ray, interpreted as basal radials. The basal supramarginals tend to be pentagonal in outline and the dorsal interradians are more or less broadly triangular or rhomboidal triangular, with the blunted apex of the triangle directed toward the suture between the basal supramarginals. In the accompanying figure, these outlines are best indicated in the interbrachial areas between rays I and V. In the other interbrachial arcs, the dorsal interradians tend to have a shallow indentation on the proximal margin. In the arc between rays I and V, the proximal halves of the basal supramarginals are separated by a rhomboidal triangular area (*m*) filled by a material distinctly darker than that of the abactinal plates, and, although occupying the position of a madreporite, its interpretation as such is extremely doubtful, especially in view of the absence of distinct radial striations. Similar dark material appears to occur in the sutures between some of the other plates on the abactinal surface. The plates interpreted as basal radials (*r*) are broadly pentagonal, with the very obtuse apex directed toward the distal end of the rays. In the accompanying figure, its outline is best shown on ray V, its blunt apex being directed slightly downward and toward the right, the plate being slightly displaced.

Between the basal radials and the nearest basal supramarginals there are one or two narrow, transversely elongated plates. The integument of the abactinal part of the disk apparently broke loose from the proximal end of rays III and IV, and contracted toward the opposite side of the disk, causing the disk plates on that side to be thrust more or less beneath the ring of plates forming the margin. Possibly the circular plate, marked *C* in the accompanying figure, is the centro-dorsal. Several plates of nearly equal size are slightly reniform in outline, but their original location is uncertain. Apparently, the remaining plates of the disk were of smaller size, some of them much smaller than others, but nothing can be said of their arrangement. In the accompanying figure the larger cross indicates the center of the disk as suggested by the present arrangement of the ring of marginal plates. The smaller cross gives another possible position for this center, if shrinkage of the integument be supposed to have caused a moderate lateral spreading of that part of the marginal ring which remained intact.

Abactinal area of rays consisting distally of three columns of plates, the two columns of supramarginals and the intermediate column of radials. The radials here are distinctly smaller than the supramarginals, forming with the latter transverse groups, each consisting of three plates, the spaces in the angles between two consecutive radials and the two adjoining supramarginals, on each side, being apparently vacant. The distal margin of each radial tends to overlap slightly the proximal margin of the adjoining radial. The proximal margin of the supramarginals tends to overlap slightly the distal part of the two adjoining supramarginals, while that part of the lateral margin which adjoins the neighboring radial is slightly pointed and tends to overlap the margin of this radial. That part of the ray in which the column of the radials is distinctly defined forms about seven-tenths of its length. Proximally, for the remaining three-tenths of its length, it is difficult to determine with certainty which plates are to be regarded as belonging to the column of radials. In the accompanying figure, on plate V the outlines of the radials, in the distal parts of the rays, and also the outlines of the sup-

posed radials, in the proximal parts of the rays, have been darkened. Only a small portion of these supposed radials is seen in certain cases, due to hiding beneath the overlapping accessory plates, intervening between the columns of radials and supramarginals. Proximally, there appear to be two columns of the accessory plates. These plates are ovate in outline, the more or less pointed ends being directed diagonally both toward the distant end of the ray and toward the radials, more or less overlapping the latter. The original arrangement of plates appears to have been disturbed least in the proximal parts of ray II; in ray V, the basal supramarginal and the two adjacent plates of the same series have been crowded inward, permitting only the tips of several of the adjacent accessory plates to show; otherwise the plates of the proximal part of this ray are but little disturbed.

The number of supramarginals in each column, exclusive of the basal supramarginal, apparently varies between 17 and 19, of which the distal two or three are much smaller than those immediately preceding. The most distal accessory plates occur at the side of the fifth, sixth, or seventh of the supramarginal plates, not counting the basal plate of the series. It is difficult to interpret the distal parts of rays II and IV without assuming the presence of supernumerary plates in the radial series, one or two supernumerary plates occurring also in three of the supramarginal series.

All of the rays expose some of the inframarginals, the longest continuous series being exposed on the sinistral side of ray I and on both sides of ray II. The number of these inframarginals appears to be slightly greater than that of the supramarginals, so that while they alternate with the latter proximally, they are even with them laterally in more distant parts of the ray, and become alternate again farther on. The inframarginals are larger in size than the supramarginals at least in the distal parts of the rays. They form the margins of the rays and extend from the abactinal to the actinal side of the rays, and are seen best on lateral view. No ambital or accessory plates occur between the columns of supramarginals and that part of the series

of inframarginals which is exposed immediately adjacent in case of any of the rays. In ray II, the inframarginals are in contact with supramarginals as near as the sixth supramarginal, not counting the basal plate of this series. In ray I, they are in contact as near as the fifth supramarginal. On the sinistral side of ray V, the nearest inframarginal alternates with the sides of the fourth and fifth supramarginal. This suggests that if any ambitals exist the latter must be restricted to more proximal parts than any here exposed and that their number must be small.

The actinal side of the rays is exposed by the tip of ray V (see figure VB on plate IV) for a length of 15 mm. The inframarginal plates form the sides of the rays and the adambulacral plates form two additional rows, one on each side of the ambulacral groove. In number, the adambulacrals appear to equal the inframarginals, and to be directly opposite the latter, but they are of less width. The plates seen at the bottom of the ambulacral groove are interpreted as ambulacral plates, but they are not exposed well enough to permit of accurate description.

The surface of the plates, where unweathered, is minutely granular, about four granules occurring in a distance of half a millimeter.

*Locality and formation.* Five and a half miles west of Hillsboro, Ohio, at a quarry reached by going from Fairview cross-roads half a mile east and then three-quarters of a mile southward, to the southern side of the head-waters of a small stream. Here, the specimen described, a holotype, was found in the thinner-bedded layers at the top of the quarry, associated with *Brockocystis nodosarius*, *Hallopora magnopora*, *Orthis flabellites*, *Strophonella daytonensis*, and *Plectambonites transversalis*. These thin-bedded limestone layers occur  $11\frac{1}{2}$  feet above the base of the quarry. The base is formed by the more massive cherty layers which occur a short distance above the base of the Brassfield formation. Named in honor of Prof. Charles Schuchert, in recognition of his many services to American Paleontology.

*Remarks.* The most striking feature of *Mesopalaeaster schucherti* consists in the radial plates forming a distinctly recognizable series only along the more distal parts of the rays, and in

the radial accessory plates being confined to the proximal parts of the rays. In the more proximal parts of the rays it is impossible to pick out, with any degree of confidence, those plates which are to be regarded as belonging to the radial series. The nearer accessory plates either equal or exceed the radials in size, and the latter either are partially covered or are more or less displaced, so that they can not be identified as radials. While not in the direct line of descent from *Hudsonaster* to *Palaeaster*, this species indicates how *Palaeaster* may have originated by the introduction of radial accessory plates and by the displacement of the radials, the latter diminishing in size and finally disappearing altogether distally.

It is evident that the genus *Mesopalaeaster* will be broken up into various subgenera or genera as the species at present referred to this genus become better known. The beginning has been made by W. K. Spencer, who founds the new genus *Caractacaster* on the Ordovician species *Palaeaster caractaci* Gregory, from the Caradoc sandstone of Wales and of the Welsh border, characterizing this genus by the presence of a continuous series of radials, bordered on each side by a column of small radial accessory plates which extends the entire length of the rays. For *Mesopalaeaster schucherti* the subgeneric name *Hemipalaeaster* is proposed, in view of the partial loss of a distinct series of radials, in the proximal parts of the rays.

### **Schuchertia magna** sp. nov.

#### *Plate VI, fig. 1*

*Measurements.* Radius of the disk, from its center to the nearest part of the interbrachial arcs, 13 mm. Radius from the center of the disk to the tip of the rays, 33 mm.; longer radius about 2.5 times the length of the shorter radius.

Rays separated by large interbrachial arcs, narrowing rapidly near the base, so as not to exceed 7 mm. in width at a distance of 14 mm. from the tip; narrowing thence more gradually and terminating rather bluntly.

Abactinal area composed of numerous small plates. These plates are very small near the tips of the rays and gradually increase in size toward the disk, numerous plates on the disk equalling 2 mm. in diameter. Nothing is known of the arrangement of the plates except along the distal halves of the rays where the plates are aligned in slightly oblique rows, as indicated on rays A and B of the accompanying figure. Apparently five or six of these rows occupied the width of the ray between 6 and 12 mm. from its tip. In the present state of preservation of the specimen, the larger plates, on and near the disk, appear to be irregularly interspersed with smaller plates. In the accompanying figure, the larger plates are shown best on the left side of the disk, between rays B and D.

Nothing definite is known of the surface of the plates, but a few of them present the appearance of having been strongly elevated at the middle into a prominent node.

*Locality and position.* The holotype was found about  $5\frac{1}{2}$  miles east of West Union,  $1\frac{1}{5}$  miles east of the Stone Church, where the road crosses a small creek. Here the specimen was found in the Brassfield limestone at the top of a small fall immediately beneath the bridge, 30 feet below the base of the Dayton limestone, at about the same horizon as the holotype of *Mesopalaeaster schucherti*, although the latter was found  $5\frac{1}{2}$  miles west of Hillsboro, Ohio.

*Remarks.* This specimen is of interest chiefly on account of its occurrence in the Brassfield formation. At the time of its discovery it appeared scarcely worth collecting. In outline it closely resembles *Schuchertia laxata* Schuchert, but it is distinctly larger and the plates on the disk appear to have been much more irregular in size. If these plates were strongly nodose centrally, this alone would be sufficient to distinguish it from the few species of *Schuchertia* hitherto described.

The possibility of the plates being nodose centrally is suggested by an anomalous specimen (fig. 7 on plate II) found, associated with *Brockocystis nodosarius*, in the lower part of the Brassfield formation, on a hill-crest a mile northeast of the center of Manchester, Ohio. It is not known even that this specimen

is part of a starfish, but if the nodose projections were removed the plates would at least be similar in size and irregularity. The larger of these plates are 2 mm. in width and the central nodose projections are slightly over 1 mm. in width. Smaller plates have correspondingly narrower projections. All plates are of about the same thickness, about 0.8 mm., and the nodose elevations vary from a little over 1 mm. on the larger plates to about 0.6 mm. on the smaller ones. The width of the nodose elevations is slightly greater at the top than at mid-length, and they may have served as supports for spines.

**Stereoaster squamosus** sp. nov.

*Plate VII, figs. 2 A, B, C*

In its present state, the echinoderm here figured and described resembles a starfish, and as such it is here described, although structurally differing from all of the three major subdivisions of the Palaeozoic Stellerioidea so far proposed—the Asteroidea, Auluroidea, and Ophiuroidea.

Rays five, slender and gradually tapering, separated by distinct interbrachial arcs. The radius of the disk, from the center of the disk to the interbrachial arcs, varies from 4.5 to 5 mm. None of the rays is preserved as far as its tip, but from such parts as are preserved it is estimated that the radius from the center of the disk to the tip of the rays equals about 18 or 19 mm. In two of the interbrachial arcs the outline of the disk is moderately convex rather than concave.

Only the actinal side of the specimen is exposed, but this side of the specimen appears considerably worn so that almost all of the plates actually exposed undoubtedly belong to the abactinal part of the integumentary skeleton, only the inner surfaces of the abactinal plates being visible in most cases.

In the interbrachial area between rays I and V, as designated on the accompanying figures, there is a broad, flat, scale-like plate. Between this plate and the center of the disk, the bevelled-off inner margins of at least four additional similar plates are exposed. These plates overlap each other in such a manner

that in each case the slope is from the upper, distal margin toward the lower, proximal margin of the plate, forming an angle of about 15 degrees with the horizontal plane of the specimen. The surfaces of contact between these plates are finely striated in a direction perpendicular to their inner margins, similar to the striations on the inner surfaces of contact on some of the larger scales of some of the Ordovician Agelacrinidae. In the specimen here described these plates evidently were closely articulated, and probably were held rigidly together, or were only slightly movable.

In the interbrachial arc between rays I and II, and also between rays IV and V, there are several plates of which those near rays I and V are shorter, while those near rays II and IV are longer, in a radial direction. When viewed from the interior of the disk, these plates or series of plates tend to slope in the same direction as those between rays I and V, already described.

Large, flat, scale-like plates are present also between rays II and III, and between rays III and IV. These also are finely striated in a direction from their distal toward their proximal margins, along their surfaces of contact. They slope somewhat as the interbrachial plates between rays I and V, rising laterally toward rays II and IV, and inclined more or less downward toward ray III.

Mr. Austin H. Clark, of the United States National Museum, kindly showed the writer various Ophiuroidea with more or less overlapping scale-like plates, but in these Ophiuroidea the symmetry was plainly radial, while in the specimen here described the symmetry seems more bilateral, as far as the arrangement of the scales of the disk are concerned. Unfortunately the upper surface of the disk is not visible. On the basis of at least partial bilateral symmetry, the interbrachial arc between rays I and V is regarded as the posterior part of the disk.

The outlines of the inner surfaces of the abactinal plates of the rays are exposed best in case of ray IV. As here exposed, the plates are irregular in size, form, and arrangement; there appears to be no arrangement in longitudinal series, corresponding to the radials, marginals, and inframarginals among the

Stelleroidea. In its present state of preservation, the most striking feature of this ray is the irregular series of short vertical pores along the anterior side of the concave depression traversing the actinal side of this ray longitudinally. These pores vary from 0.25 to 0.33 mm. in depth, and tend to occur in pairs, the members of each pair being less than 0.5 mm. apart, or sometimes so close together that two pores are included in the same general depression, appearing as separate pores only at the bottom of the larger elliptical pore formed by their union.

A similar irregular series of vertical pores occurs along the anterior side of the longitudinal depression following the actinal side of ray II. Pores are not seen on the proximal parts of ray III, but on the distal part several pores occur along the middle of the longitudinal depression there visible. Vertical pores exist also along the middle of the deep depression following the actinal side of ray V. In the case of ray I, that part of the longitudinal depression which might show pores is over-arched by other plates, not seen on the other rays, probably because not preserved there. No explanation for the presence of these pores can be offered. They appear closed at their inner extremities, and apparently bear no relation to the podial canals among the Auluroidea. At first they were regarded merely as borings, subsequent to the death of the animal, but in that case there appears to be no reason why their presence should be confined practically to definite parts along the longitudinal depressions following the actinal side of the specimen. The depression marked *a* in figure 2C on plate VI accompanying this paper probably represents an ordinary boring, and is quite different in size and depth from the pores just described. Moreover, there is no appearance of pairing in this case.

The plates forming the abactinal side of the specimen, and these are almost the only plates here exposed, are so thick, and are so closely appressed at the sutures, that they must have been almost immovable. The thickness of the plates varies between 0.6 mm. to almost an entire millimeter, and may exceed this amount in some parts of the specimen, nearer the disk, where measurements, in the present state of exposure of the specimen, are impossible.

In the case of ray I, what is regarded as the ambulacral groove is overarched, at least proximally, by a number of small plates not seen on the other rays. The outlines of only a few of these small plates can be distinguished, and these do not suggest any analogy with the ambulacral and adambulacral plates among the Asteroidea. The arching plates, except at the proximal end of the ray, appear to be thin, and appear to sag readily into the ambulacral groove. Similar over-arching plates may have existed formerly over the proximal ends of the ambulacral grooves of all of the other rays, but, in the present worn condition of the specimen no trace of these plates can be detected. The proximal half of ray III at present shows no trace of the ambulacral groove, probably on account of weathering, but the longitudinal depression formed by this groove is retained on the distal half of the ray, and here the short vertical pores already described occur along the central part of this depression.

*Locality and position.* Associated with *Dimerocrinus* (?) *vagans*, within  $2\frac{1}{2}$  feet from the top of the Brassfield limestone, at a locality reached by going from Byron, Ohio, 1 mile east and then 1 mile southeast. The exposure occurs in a shallow wet-weather stream bed, east of the road. In a direct line this exposure is less than seven miles northwest of Xenia.

*Remarks.* The affinities of this species among the Echinodermata are highly problematical. The arm structure does not resemble even remotely that of the Ophiuroidea or Auluroidea. The entire absence of any structure resembling ambulacrals and adambulacrals excludes it from the Asteroidea, even from the Cryptozonia division of the Asteroidea. The specimen here figured and described is the only one found in many years of collecting, and there seems no prospect of securing additional illuminative material in the near future; hence its present publication.

The excellent photographs forming the basis of the accompanying figures were prepared by Dr. Herrick E. Wilson, of the U. S. National Museum.

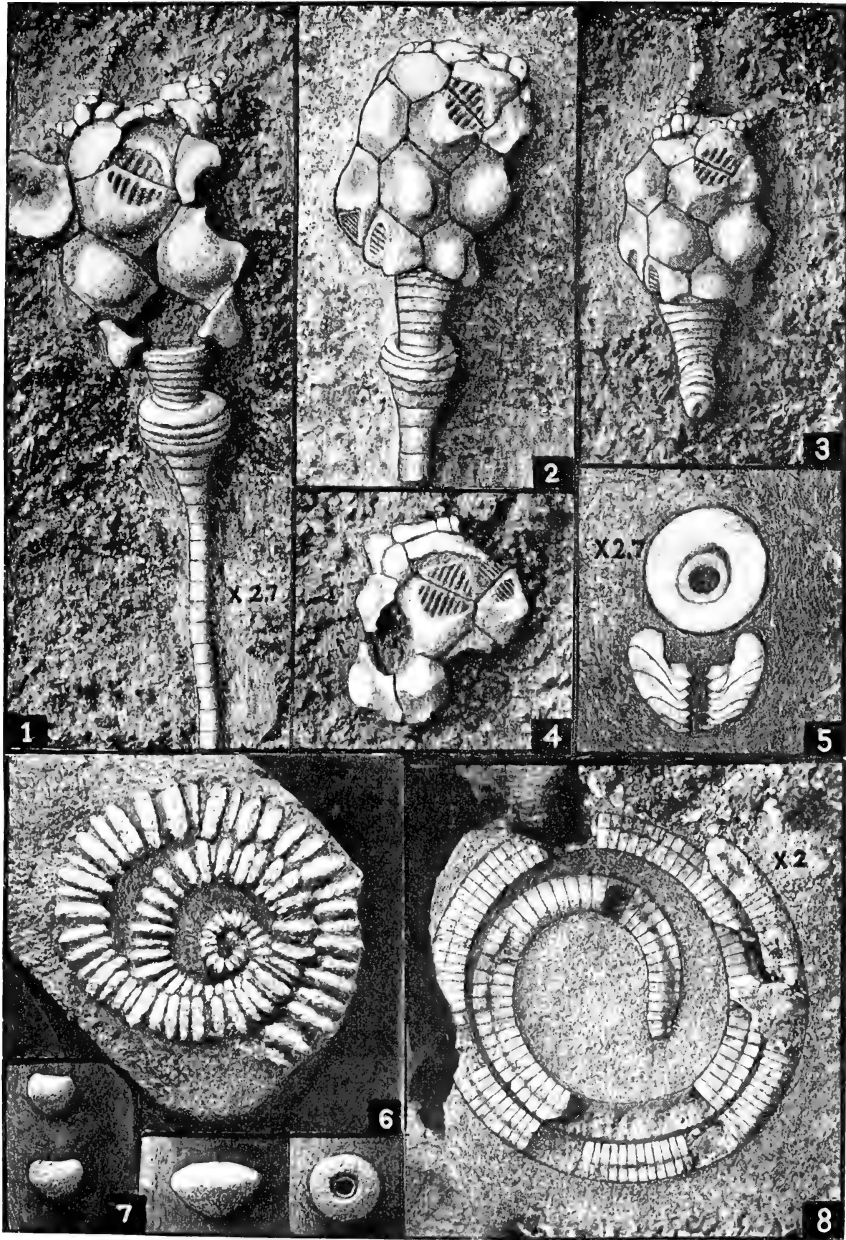
## PLATE I

Figs. 1-5. *Brockocystis nodosarius* sp. nov. The pectinirhomb on plates 12-18 is seen in figures 1, 2, and 3; the last two of these figures show also the pectinirhomb on plates 1-5; in each figure the anal area is on the right, the two plates bordering on the left side of this area being included in the figure. Figures 1 and 3 show traces of the brachioles. The pectinirhombs on plates 14-15 and 10-15 are shown by figure 4; the anal area is included in the lower left hand corner of the figure. The pyriform enlargement of the column, a short distance below its top, is shown in figure 5, presenting both a horizontal and a vertical section, indicating the origin of this enlargement from the coalescence of a number of columnals. All figures enlarged 2.7 diameters. From 2 miles west of Peebles, Ohio; Brassfield formation.

Fig. 6. Coiled crinoid stem. From Brassfield formation, 1 mile northeast of Wilberforce, Ohio. For illustrations of separate columnals see plate II, figures 5A, B, C.

Fig. 7. *Brockocystis tecumseth* (Billings). Enlargements of the top of the column, due to coalescence of several of the columnals. Three lateral views, showing variation in outline; one specimen viewed from the top, showing area of articulation. Cataract formation; half a mile east of Ice Lake, on road from Gore Bay to Kagawong, on Manitoulin Island. Shown in contrast with similar enlargements of the column in *Brockocystis nodosarius*.

Fig. 8. *Eomyelodactylus rotundatus* sp. nov. Coiled column, terminating at the center at the point where reversal of curvature took place. In by far the greater part of its length this column has been split in half, and only the split surface is seen, exposing the lumen. See plate II, figure 3, for a cross-section of this column. Brassfield formation; nearly 5 miles southeast of Xenia, Ohio.



FOERSTE: OHIO BRASSFIELD ECHINODERMATA

## PLATE II

Fig. 1. *Clidochirus ulrichi* sp. nov. A. Enlarged view of calyx and arms, showing the anal side. B. Same specimen, with column attached. Dayton limestone; southeast of Soldiers' Home, west of Dayton, Ohio.

Fig. 2. Lepadocystid plate. Single plate of unknown species of Lepadocystid. Brassfield formation; 1 mile northwest of Cowlesville, Ohio.

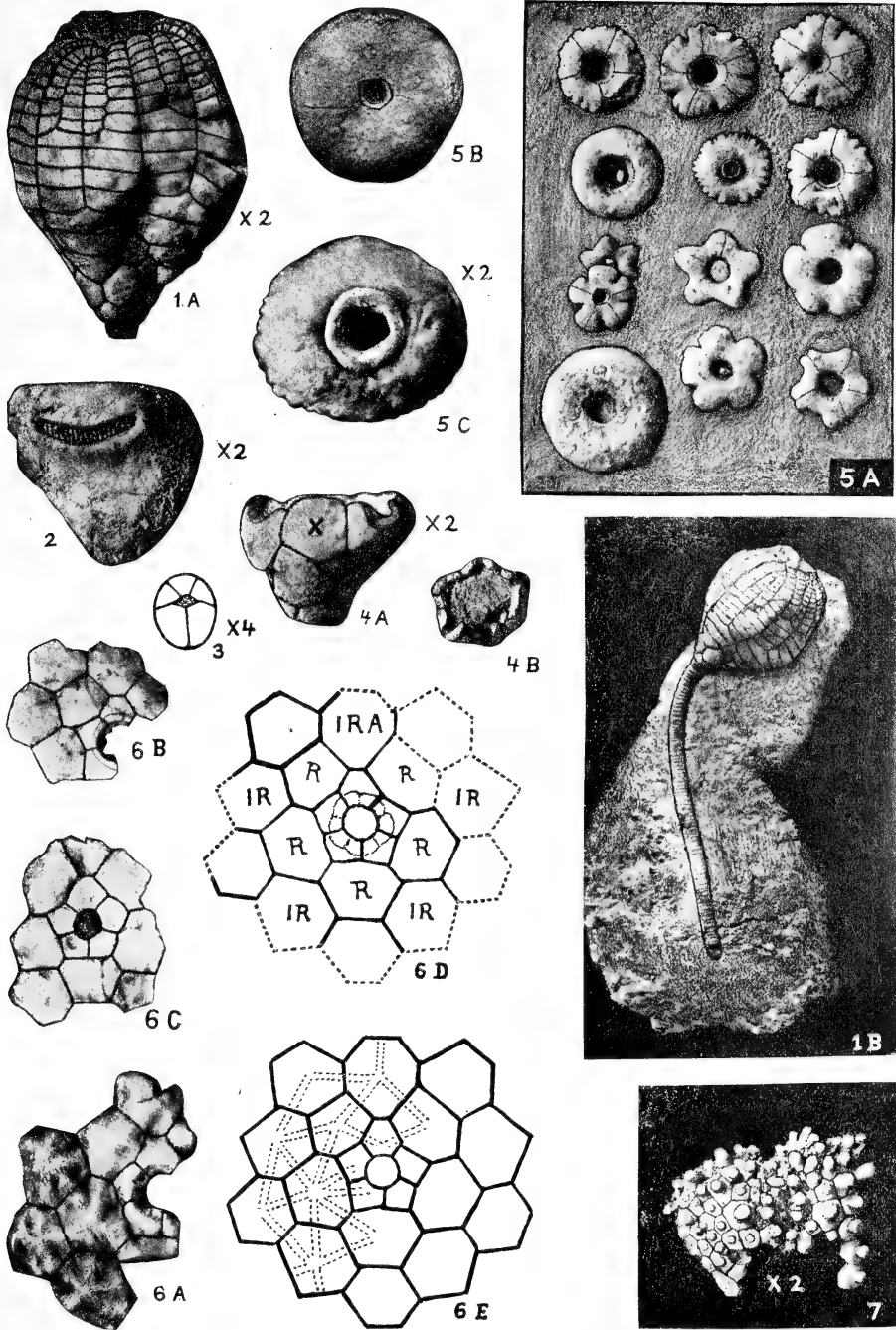
Fig. 3. *Eomyelodactylus rotundatus* sp. nov. Cross-section of column of specimen represented by figure 8, plate 1.

Fig. 4. *Botryocrinus* sp. A. Lateral view of calyx, anal side. B. Top view of same specimen. Holophragma zone at top of Upper or Lilley division of West Union formation; Zink quarry in eastern margin of Hillsboro, Ohio.

Fig. 5. Crinoid columnals. Columnals of same species as that forming the coiled column illustrated by figure 6, plate I. A and C from Soldiers' Home quarry, west of Dayton; B from Centerville quarry, Ohio.

Fig. 6. *Dimerocrinus* (?) *vagans* sp. nov. A, B, and C. Fragments of the base of calyces, all with anal side at top of figure; A, B, exterior views; C, view from interior side of calyx. D. An attempt at a restoration of the basal part of the calyx, based on various specimens. E. Figure indicating the direction of the radiating lines ornamenting the plates. Brassfield formation; about 1½ miles southeast of Byron, Ohio.

Fig. 7. Echinoderm plates. Numerous small plates of an echinoderm, each plate ornamented by a small central abruptly elevated protuberance. For description, see paragraph following remarks on *Schuchertia magna*.



FOERSTE: OHIO BRASSFIELD ECHINODERMATA

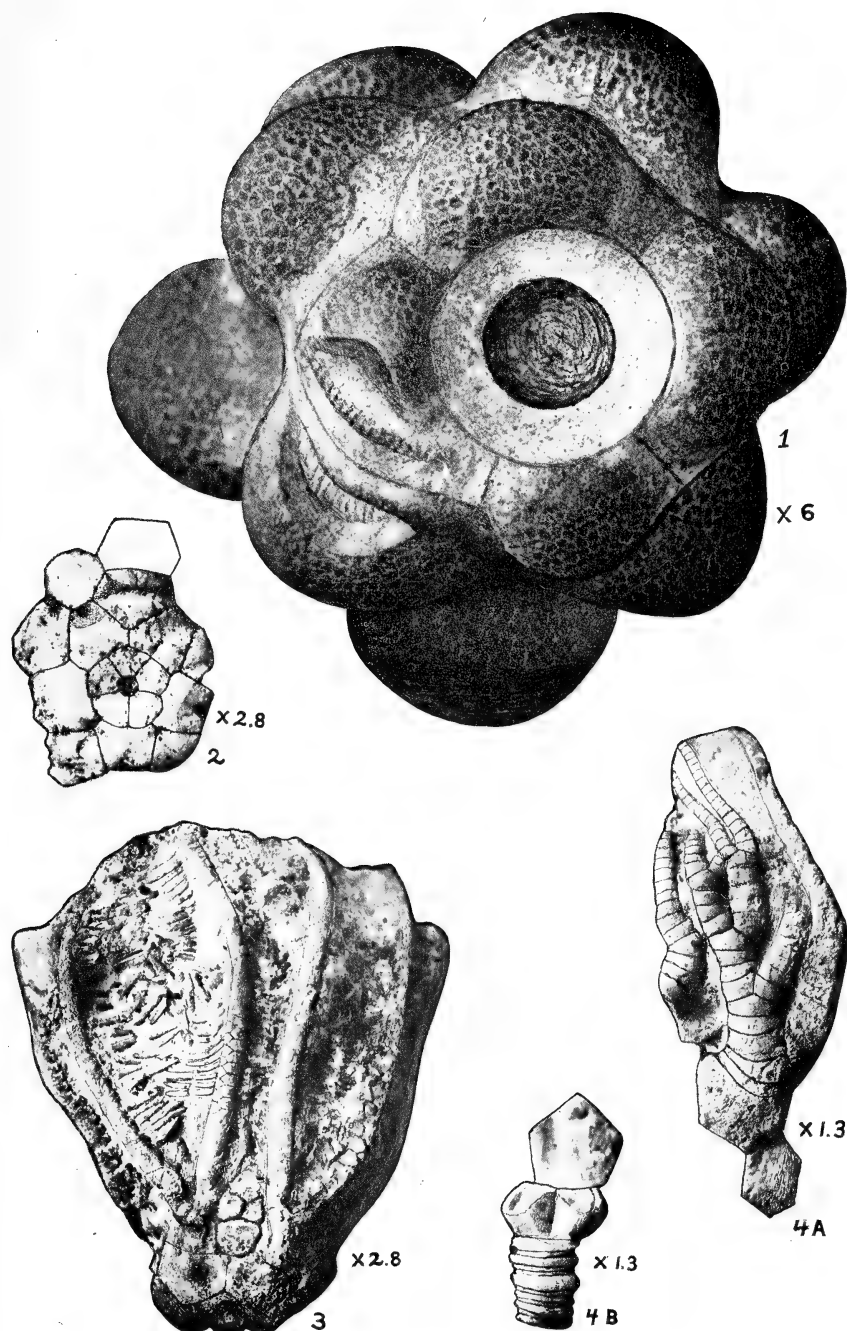
### PLATE III

Fig. 1. *Brockocystis tecumseth* (Billings). Basal view of theca, showing large lumen at area of attachment, the pectinirhomb on plates 1-5, and the reticulated surface of the plates. For additional illustrations of the same specimen, see Bull. Sci. Lab. Denison Univ., vol. 17, pl. V., figs. 2A, B, C; the characteristic globular or pyriform aggregations of columnals of this species are figured on plate I of the present paper. From Manitoulin Island, east of Ice Lake, on the road from Gore Bay to Kagawong.

Fig. 2. Undetermined crinoid. Basal part of calyx of some unknown crinoid, with five infrabasals. Top of Brassfield formation; southeast of Byron, Ohio.

Fig. 3. A *Platycrinid* (?). Calyx and arms apparently belonging to the *Platycrinidae*; however, the margins of the plates are not defined clearly enough for accurate determination. From the soft clay at the top of the Brassfield formation at Centerville, Ohio. *Platycrinus corporiculus* Ringueberg (Bull. Buffalo Soc. Nat. Sci., vol. 5, 1886, p. 12, pl. I, fig. 9) from the Rochester shale at Lockport, N. Y., is a somewhat similar dubious form.

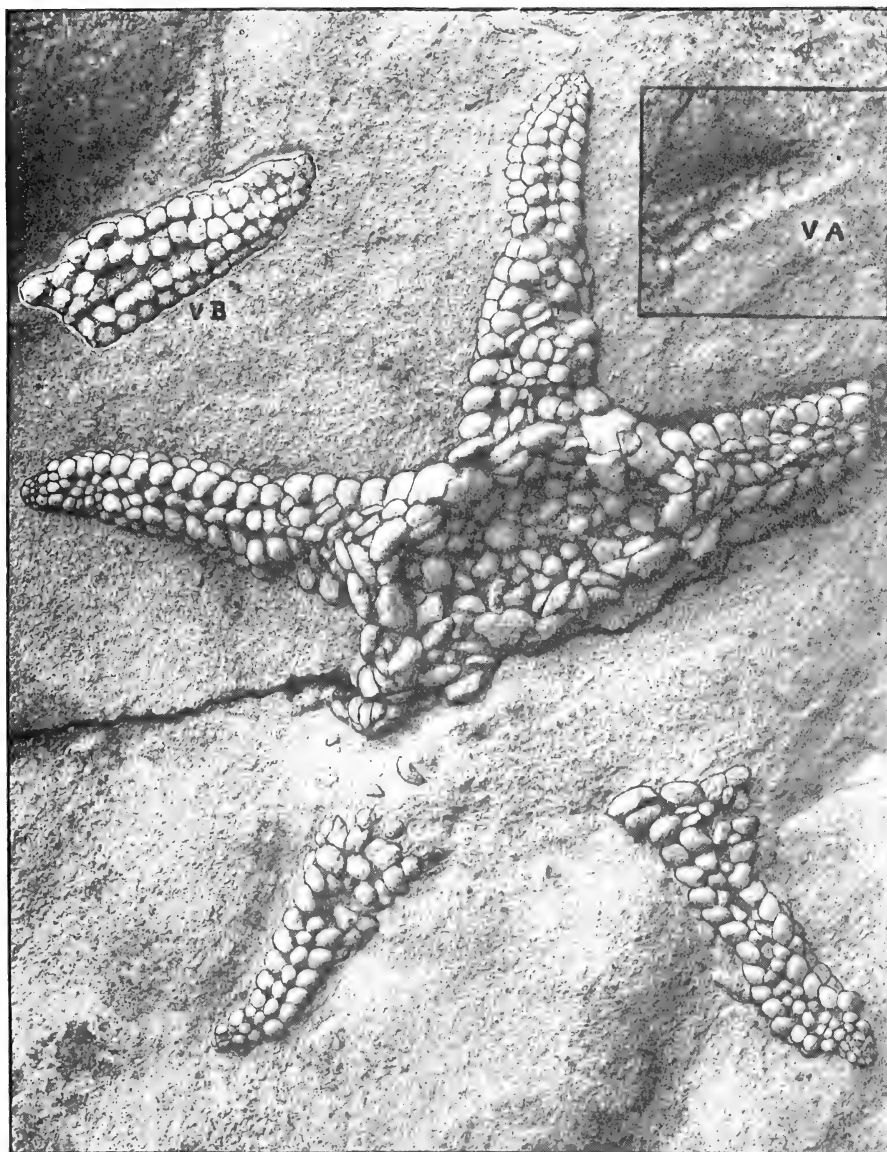
Fig. 4. *Cyathocrinus* (?) sp. Parts of a crinoid with very thick plates, possibly a *Cyathocrinus*. A, a radial followed by two costals, the axillary costal supporting two arm-branches, of which only the left one is well preserved. The latter has three distichals, and again only the left branch of the succeeding arm-branch is well preserved. B, top of column with 2 very thick infrabasals still attached, also one of the basals. From the soft clay at the top of the Brassfield formation, at the Centerville quarry, Ohio. In vol. 3, Bull. Sci. Lab. Denison Univ., on plate 8, figure 42 presents one of the radials of this species, and figure 43 probably represents one of the basals. Figure 44 may be one of the axillary plates of the arm system. All of these earlier figured specimens were obtained from the soft clay at the top of the Brassfield formation, at Soldiers' Home, west of Dayton, Ohio.



FOERSTE: OHIO BRASSFIELD ECHINODERMATA

#### PLATE IV

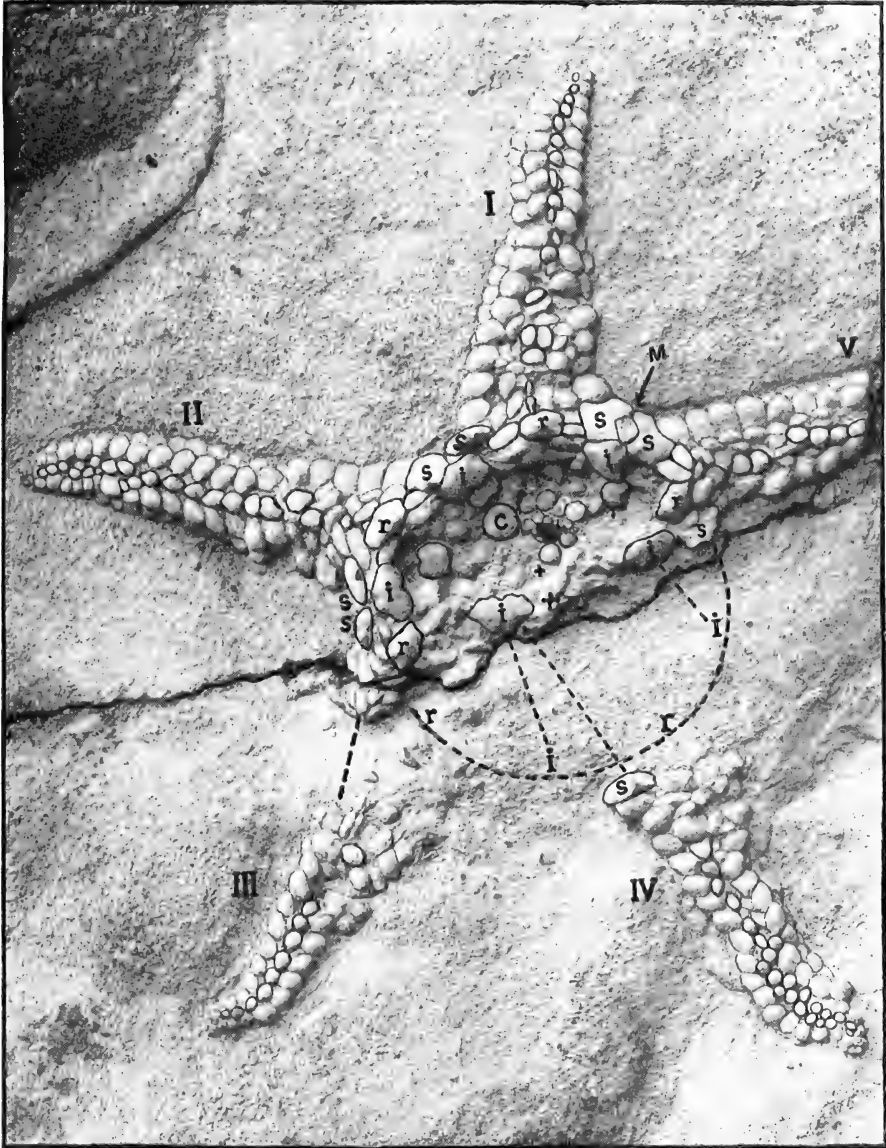
*Hemipalaeaster schucherti* sp. nov. . Abactinal side of an almost entire specimen, enlarged about 2.1 diameters. Before complete burial, the margin of the disc appears to have rotted away from the proximal parts of rays III and IV, and to have shrunk away from the latter. In collecting the specimen, the tip of ray V broke off, and the impression left by this ray in the top of the limestone is shown by figure VA; the actinal side of this tip is represented by figure VB. The lateral margins of this second figure are formed by the inframarginals; the other two rows of conspicuous plates are the adambulacrals. For comments on the remainder of the specimen see the descriptive material accompanying the diagrammatic indications on plate V. From the top layers in the quarry, 5½ miles west of Hillsboro, Ohio, reached by going from Fairview cross-roads half a mile east, then three-quarters of a mile south, crossing the headwaters of a small stream to a quarry in the lower half of the Brassfield formation.



FOERSTE: OHIO BRASSFIELD ECHINODERMATA

## PLATE V

*Hemipalaeaster schucherti* sp. nov. The rays are numbered from I to V. In each ray, the radial plates are indicated by darkening their outlines. In the distal parts of the rays this may be done with some accuracy; in the more proximal parts this is all guess-work. The basal supramarginals are indicated by *S*, and from these plates the remaining supramarginals may be traced readily as far as the tips of the rays. The inframarginals are well seen on the left side of ray I, and on both sides of ray II, along the more distal two-thirds of the rays. The dorsal interradials are indicated by *i*. The plates indicated by *r* may correspond to the basal radials of other species, but this is very doubtful. The former extent of the disc of this specimen is indicated by the broken circle. The two plates which are marked *i*, and which are enclosed by this broken circle, resemble the dorsal interradials in outline and are believed to have been located originally at the points on the circle with which these plates are connected by dotted lines. The original center of the disc probably was located near one of the two small crosses. The plate marked C may correspond to the centrodorsal of other species, but this is highly problematical. Moreover, the correct interpretation of the apparent opening toward the right of plate C is prevented by its poor state of preservation. If the plate marked M is the madreporite, it does not resemble the corresponding one in *Palaeaster niagarensis*. The arrangement and general appearance of the basal supramarginals and of the dorsal interradials, however, is similar.

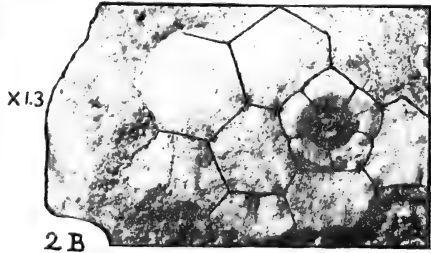
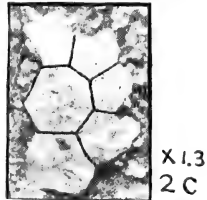
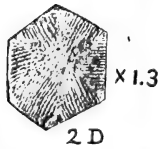
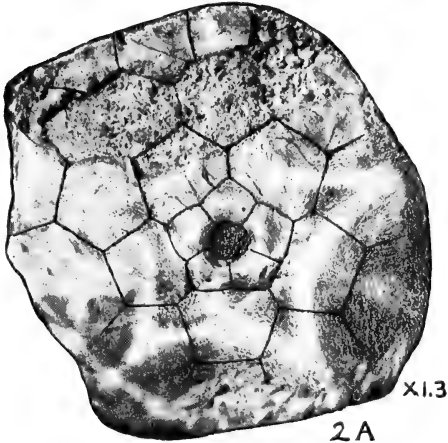
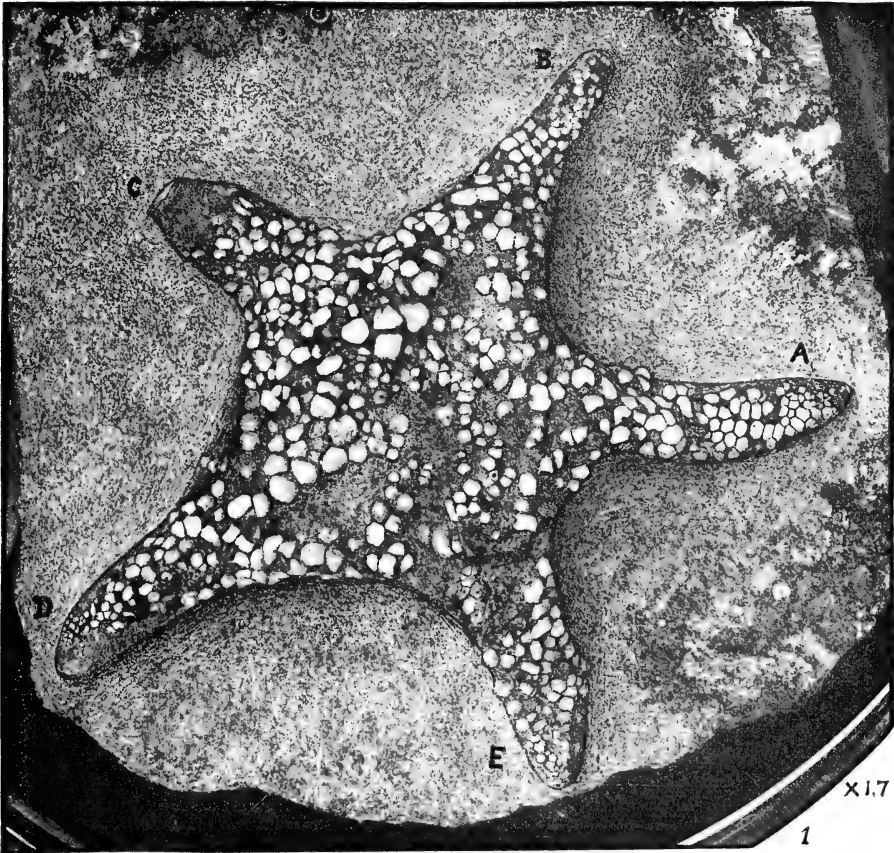


FOERSTE: OHIO BRASSFIELD ECHINODERMATA

## PLATE VI

Fig. 1. *Schuchertia magna* sp. nov. A poorly preserved specimen, enlarged 1.7 diameters, photographed under water so as to bring out the individual plates. Most of these have been displaced. Near the tip of ray A most of the plates still occupy their original relative position; this is true also of some of the plates on the distal halves of rays B and E. Those of the central part of the specimen evidently have been much displaced. The specimen is valuable chiefly in presenting the general form and size of the species. About  $5\frac{1}{2}$  miles east of West Union,  $1\frac{1}{2}$  miles east of the Stone Church, where the pike crosses a small creek. Here the specimen was found in the Brassfield limestone, 30 feet below the base of the Dayton limestone, at the top of the limestone exposure immediately beneath the bridge. The horizon is regarded as approximately the same as that of *Hemipalaeaster schucherti*, although the latter was found over 5 miles west of Hillsboro, Ohio.

Fig. 2. Unknown crinoid. A, base of calyx with traces of the low ridges ornamenting the plates; in the figure these traces are emphasized. B, a second specimen, preserving better the articulating surface for the attachment of the column. C, several additional plates. D, one of the plates, preserving the surface ornamentation. From the area a mile and a half southeast of Byron, Ohio, at the top of the Brassfield formation. Figure 41 on plate 8, vol. 3, Bull. Sci. Lab. Denison Univ., appears to represent the same species. The same figure is seen on plate 27 of vol. 7 of the Ohio Geological Survey, published in 1895.

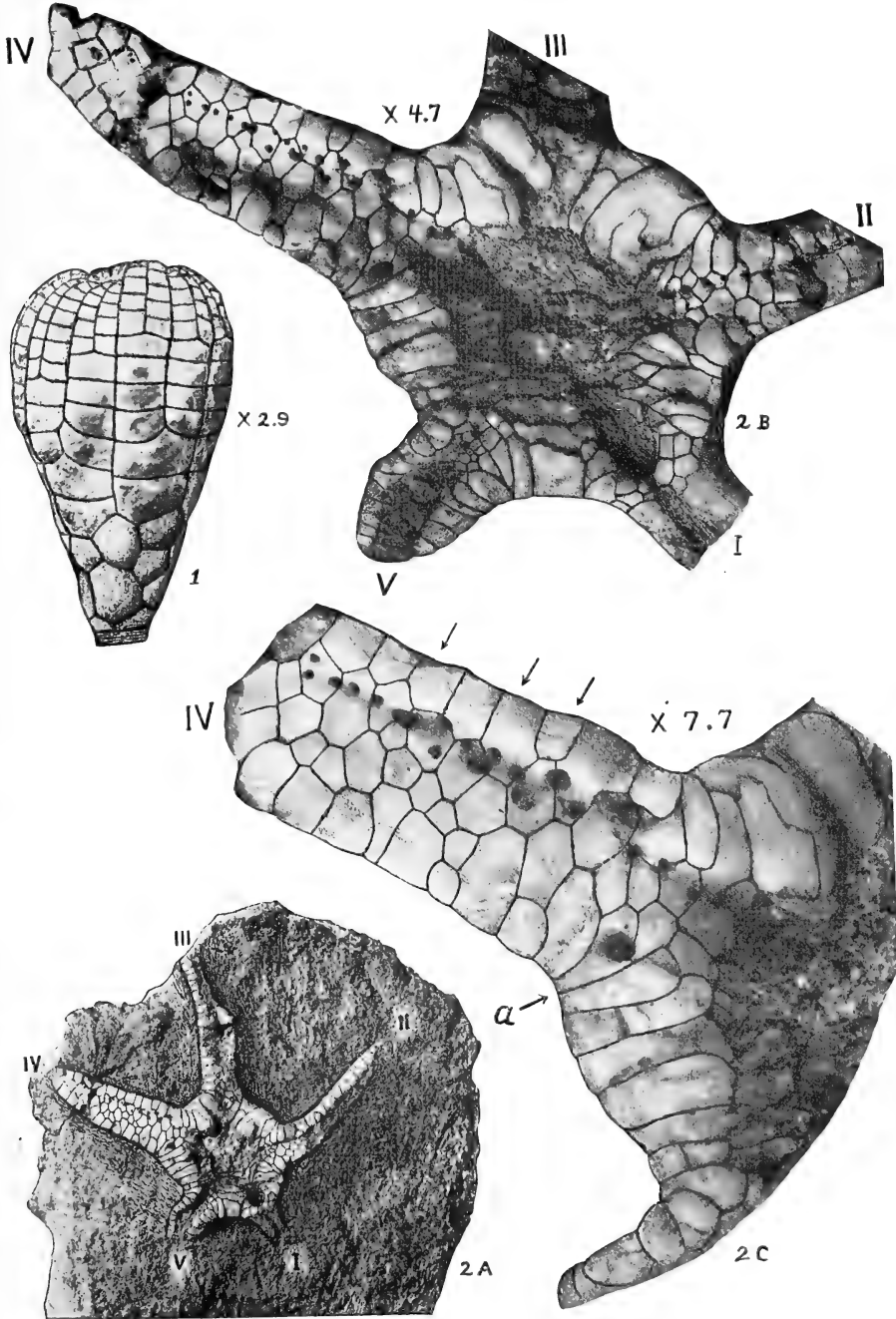


FOERSTE: OHIO BRASSFIELD ECHINODERMATA

## PLATE VII

Fig. 1. *Clidochirus* sp. Species described by Springer. Anal side of calyx with arms attached. From the soft clay at the top of the Brassfield formation at the quarry northwest of the railroad station at Centerville, Ohio.

Fig. 2. *Stereoaster squamosus* sp. nov. A, entire specimen, actinal side. B, the greater part of the same specimen enlarged. C, a part of one of the arms enlarged still further. The arms are numbered with Roman numerals. The arrows in figure 2C point to depressions within which the pores are seen to occur in pairs; the letter *a* in the same figure points to a large pit for which there appears no structural reason. The overlapping of the plates within the central area is seen best within the lower, lefthand side of this area, and near the basal parts of ray II in figure 2B. There is no evidence of system in the arrangement of the plates, such as would be expected among the *Stelleroidea*.



FOERSTE: OHIO BRASSFIELD ECHINODERMATA



## AMERICA'S ADVANCE IN POTASH PRODUCTION<sup>1</sup>

W. C. EBAUGH

### INTRODUCTION

In a paper presented early in 1917,<sup>2</sup> it was pointed out that the world faced an emergency of greatest consequence, due to its inability to get potash for agricultural and industrial uses, and the hope was expressed that the Great War might lead to cheap potash, just as the Napoleonic wars of the preceding century had led to cheap soda. Events of the last two years apparently justify the belief that this hope has turned to fact, and that economic independence, so far as potash is concerned, has been won by a victory no less remarkable in its way than that achieved by arms.

The antitheses of war are striking. Men, women and children have pain, mutilation, starvation and death forced upon them, are torn loose from their abodes and possessions, and scattered broadcast as refugees; yet never are bravery, coöperative action, fellowship of all classes, and self-forgetfulness more in evidence. Science and industry run amuck, labor on a gigantic scale is turned from constructive to destructive work, the normal markets and trade routes are closed, and wastage is enormous; yet inventive genius, medical skill, sanitation, conservation, substitution of new raw materials for those no longer available, and the introduction of new methods of manufacture and distribution come to a nation's relief. National hate, greed, duplicity, rapacity, ruthlessness and cruelty find their counterparts in love and sympathy for one's allies, generosity to war victims at home and abroad, the introduction of "blue sky

<sup>1</sup> An address prepared for the regular semi-monthly meeting of the Denison Scientific Association, December 17, 1918.

<sup>2</sup> W. C. Ebaugh, Potash and a world emergency, Jour. Indus. Eng. Chem., vol. 9, p. 688, 1917.

diplomacy," and the abolition of secret treaties, the organization of benevolence on an unprecedented scale, and the expenditure of time and money to repair wastage—not for self, but for those who would have been considered aliens, beyond the pale of one's normal interest a few months ago.

It has been well said that the sinews of war are men, munitions or material, money and morale. In the second category come explosives and the enginery of war, clothing, shelter and food. And the greatest of these is food—food not only for men at the front, but for all the people of the nation at war. The maximum production of food without fertilizers is impossible, and Liebig's doctrines that phosphates, nitrogen and potash must be put into soils to replace these constituents removed with crops and transported to distant places, have found ever increasing acceptance since they were published some seventy-five years ago. Of these three plant foods, the Allies and the United States had access to phosphates and nitrogen in sufficient amounts, but in the case of potash, Germany was sole dictator. In fact, her control of this great natural monopoly constituted her "one big economic weapon" which she threatened to use in such a way that the nations of the world would be brought starving to her doors, begging for potash that they might have bread!

#### STASFURT DEPOSITS

The story of Stasfurt salt deposits is one of great interest. For centuries salt had been obtained from this district in north central Germany, near Magdeburg, and the deposits are known to be at least 100 square miles in area, with strata 3 to 4 inches thick and with some 15,000 "rings" or layers, indicating that the salt required at least 15,000 years for its deposition. Judging from workings down to the 3300 foot level, it has been estimated that brine, from which these salts came, would have covered the earth to a depth of 50 miles, that the temperature during at least a part of the time evaporation was taking place, varied from 80° to 160°F. and that "conditions for air evaporation were exceedingly favorable during the Permian period."

Borings were begun in 1837, salt was encountered in 1843, and shafts were sunk between 1851 and 1856. Disappointment ensued, because "bitter salts" and not rock salt, were found. But the value of these "bitter salts" as a source of potash was soon recognized. Frank, a sugar chemist, worked out a method

SHORT TONS

300 000

200 000

100 000

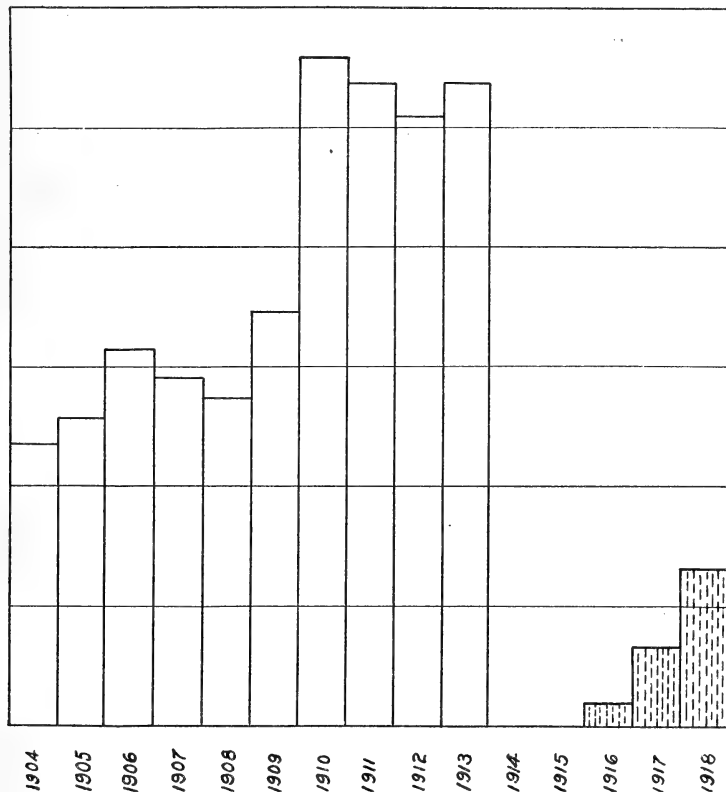


FIG. 1. Imports (open rectangles) and domestic production (shaded rectangles) of potash ( $K_2O$ ) in United States 1904-1918.

for extracting potassium chloride from the mixed sodium-potassium-magnesium salts, and the first factory was erected in 1861. From that time until 1914 Germany monopolized the world trade in potash.

The extent of Germany's exports of potash to the United States is shown in the accompanying diagram (fig. 1). Although

both crude and refined salts are shipped, for purposes of comparison all are calculated to a "potash" or " $K_2O$ " content. In 1912 the exports from the German Empire and the imports into the United States were:

	EXPORTS FROM GERMANY	IMPORTS INTO U. S. A.
	<i>met. tons</i>	<i>met. tons</i>
Crude potassium salts .....	1,300,559	650,297
Potassium chloride .....	286,528	190,775
Potassium sulphate.....	85,452	35,366
Potassium magnesium sulphate .....	48,540	14,172
	1,721,079	890,610*

\* Equivalent to 65 cars, 100,000 pounds capacity, six days a week throughout the year.

This immense amount of potash was consumed very largely (about seven-eighths) in the fertilizer industry, and found its chief use in the south-eastern part of our country. Cotton, tobacco and cereals are the chief crops requiring potash fertilizers.

#### WAR AND THE BLOCKADE

With the catastrophe of war, the allied nations and the United States faced a desperate situation. Stocks of potash on hand were relatively small, and no other source than that in Germany was available. Even deposits—similar to those at Stasfurt—said to exist in Alsace-Lorraine, were in territory controlled by the Central Empires. The law of supply and demand was illustrated at once—prices soared from the ordinary level (a little under \$40 per ton) to unheard of heights, but even then potash could not be had (fig. 2).

The technical press soon echoed Germany's boast that a starving world would be brought begging on its knees for potash fertilizers, and let it be known that this was the one great economic weapon possessed by the enemy. America's response was immediate. A search for potash, both on the part of governmental bureaus and of private parties, was begun, and the country

was examined as never before for this substance. Other nations joined in the search, but nothing comparable to Stasfurt could be found. Under these conditions, therefore, it is not strange that efforts were put forth to secure potash from industries of the "war-baby" type, and to recover it as a by-product from existing plants. The success attending these efforts is remarkable.

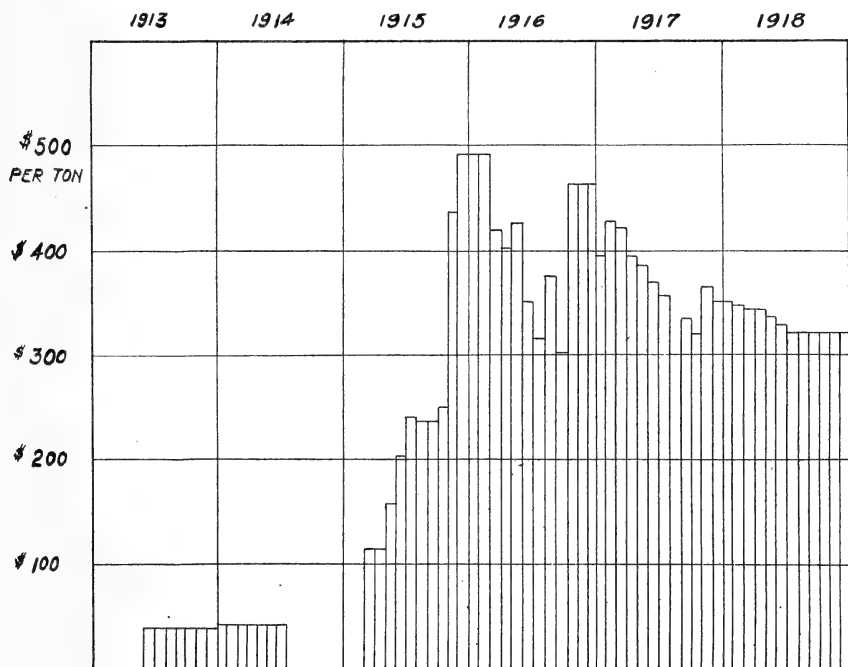


FIG. 2. Monthly prices in dollars per ton for "potassium muriate" (80 per cent), 1913-1918.

#### INORGANIC SOURCES

*a. Lakes and brines.* In 1912 some students from the University of Nebraska filed claims on certain alkaline lakes in the western part of their state, and during 1914 development of an alkali industry was begun. The treatment of the brine is very simple; it is pumped into settling tanks, evaporated in vacuum pans similar to those used in sugar factories, crystallized and

shipped in a crude state. The commercial product must contain 14 per cent of potash, but it is not difficult to maintain its content around 25 to 35 per cent. This industry has grown until a dozen or more plants are pumping brine from lakes over an area of 230 square miles. The major part of potash produced in this country during the first two years of the war came from the Nebraska lakes.

In the eastern part of California and neighboring portions of Nevada is an immense arid area that held promise for the potash prospector. Death Valley and Panamint, names associated in the popular mind with desert, desolation and starvation, represent typical districts where deposits were looked for; men seemed to feel that potash would be found as surface deposits, not realizing that those at Stasfurt were revealed only by deep borings.

At Searles Lake, California, is found the residue of an inland sea. Salt is firm and solid for about 15 to 25 feet and then brine or loose crystals form a layer 65 to 75 feet deep. Potassium chloride occurs to the extent of 4 per cent, and the total amount of this constituent is estimated at 24,000,000 tons. A plant was installed consisting of pumps, storage tanks and triple effect evaporators capable of handling 200,000 to 250,000 gallons brine and 100,000 gallons mother liquor per day. In September, 1918, production was at the rate of 1800 tons of crude potassium salts per day, and it was expected to raise the production to 4500 tons of salts, containing 75 to 80 per cent potassium chloride, early in 1919. In other words, it was estimated that this one source would be supplying about one-eighth of the pre-war consumption of potash.

At Salduro, on the Nevada-Utah border, and at Great Salt Lake, Utah, plants have been erected for the extraction of potassium salts by processes similar to those mentioned above, and much crude potash has been shipped to fertilizer factories and chemical plants. One company has operated for years at Great Salt Lake, making common salt and sluicing the mother liquors, rich in potash and magnesia, back into the lake. Its capacity was 100,000 tons of salt per year; the enhanced value of its products now that potash brings such prices, is self-evident.

During 1917 brines supplied more than 60 per cent of the total potash production in the United States.

*b. Alunite.* Alunite is essentially a basic sulphate of aluminum and potassium containing "potash" ( $K_2O$ ) to the extent of about 11 per cent in the best varieties. At Marysvale, Utah, deposits have been developed on a large scale and a steady output of potassium sulphate has been maintained. At Sulphur, Nevada, are less well known deposits.

The treatment of alunite consists essentially of roasting the mineral, usually in rotary kilns of the cement-burning type, to drive off a part of the sulphur trioxide, convert the alumina into an insoluble form and the potash into a soluble sulphate. The last named salt is then extracted with water, separated from the insoluble residue, and recovered by evaporation. As no satisfactory method for disposing of the by-product alumina has yet been made, commercially, the industry is generally viewed as being of the "war-baby type," but capable of stabilization through development of by-products when readjustment to peace conditions occurs. During 1917 the production amounted to 2400 tons of potash, or about 8 per cent of the nation's output.

*c. Cement kilns.* At Riverside, California, a cement plant was compelled to abate its dust nuisance, and applied the Cottrell process of precipitation, i.e., passing flue gases between electrically charged conductors maintained at high potential differences. The removal of 95 per cent of the solids was attained with relative ease, and to the surprise of the technical staff it was found that a large portion of this recovered dust consisted of water soluble potash, or of material that could readily be made water soluble. It is another illustration of a fact so often seen in industry—a plant is forced to correct a nuisance, and the improvements installed yield valuable products that formerly escaped, thus adding to the earning power of the plant. Modifications of this process were installed later for cement plants located at Hagerstown, Maryland, Salt Lake City, Utah, and other points, and success so far attained indicates that the adoption of this or similar systems will become general, especially in the east.

*d. Iron blast furnaces.* Gases from iron blast furnaces must be cleaned before they can be used in gas engines. The Cottrell process mentioned above has proved its value in this service, and the ores of certain districts, Alabama in particular, contain such quantities of potash that recovery of this material becomes of great economic importance. Only 200 tons of potash were made from these sources in 1917—all of which came from experimental plants—but largely increased yields are expected in 1919.

R. K. Meade has estimated that an expenditure of \$37,000,000 for potash recovery plants at iron and cement plants throughout the country would add 200,000 tons of by-product potash, or 80 per cent of our pre-war consumption, to America's output. This would be a low price to pay for economic independence in this line, and the amount involved seems small indeed when compared with war-time "drives" for \$30,000,000 for Armenian and Syrian Relief, \$170,000,000 for a United War Work Campaign, \$200,000,000 for a Red Cross Fund or a \$6,000,000,000 Fourth Liberty Loan! And the irony of fate is again evident. America's chemists and engineers have shown how to wrest Germany's "one economic weapon" from her hands by recovering and utilizing nuisance-creating material that is now allowed to go to waste on an enormous scale, by industries well established and easily able to provide necessary plants and technical skill.

*e. Manufacture from silicates.* For decades it has been recognized that the logical source of potash is silicate minerals, and much effort has been expended on developing processes to extract potash from feldspar, leucite (Wyomingite), glauconite or green sands, and similar material. Recently it has become general knowledge that tailings dumps often represent large quantities of locked-up potash; those at Cripple Creek, Colorado, run 10 per cent in potash, and those from the Utah Copper Company's mills, at Garfield, Utah, carry more than 6 per cent of this constituent. Such tailings are already finely ground and constitute the most accessible source of raw material for a silicate potash industry. The Utah Copper mills alone, treating 30,000 tons of ore daily, could supply enough raw material

(tailings) to yield 360,000 tons of potash annually, granting that only a 75 per cent extraction was made. This would be about 150 per cent of the pre-war consumption. And worthy of careful consideration is the fact that cement, also, could be obtained as a product from such a plant. The difficulties in the way are those of transportation and markets, rather than those of materials and processes; they are economic rather than technical.

Of the large number of methods proposed for treating silicates in order to obtain potash, heating with lime or magnesia and a chloride or sulphate of the alkali or alkali-earth metals, seems to be most highly esteemed. Mill tests have been so favorable that the adaptation of existing cement plants (as at Devil's Slide, Utah) and the erection of new plants (as at Green River, Wyoming) for the treatment of leucite, are now under way. Feldspar yields its potash less readily than does leucite, but even at that good extractions are to be had, and it is probable that only the fear of ruinous competition on the part of the German Kalisyndikat has prevented capital from entering this field more extensively.

Entirely unlike the processes outlined above are those proposed for utilizing glauconite or green sand. This material can be decomposed by water, or by water and carbon dioxide, under pressure at high temperatures, and quite pure potassium hydroxide or carbonate made in one operation. The by-product formed can be used for manufacturing building materials resembling sand-lime brick. Unfortunately deposits of glauconite in a sufficiently pure state are far less extensive than those of the other potash-bearing minerals.

#### ORGANIC SOURCES

*a. Suint* from wool washing gives potassium carbonate on ignition. About 300 tons of potash ( $K_2O$ ) came from this source in 1917.

*b. Beet sugar residues*, especially those from the Steffens process, gave 360 tons potash in 1917.

*c. Molasses* from cane sugar factories, and *distillery waste* gave 2850 tons of potash in 1917.

All three of these sources are capable of great expansion, but cannot be viewed as main sources of potash. The last two mentioned contain nitrogen as well as potash, and are therefore doubly valuable as fertilizers.

*d. Wood ashes.* Until 1860 wood ashes constituted the most important source of potash, the supply coming chiefly from Canada and Russia. The introduction of Stasfurt salts in 1861 killed the industry. Normally not even the dust from incinerators at lumbering camps can be worked up profitably. During 1917, however, 425 tons of potash from this source were prepared in this country.

*e. Kelp.* The collection of kelp (seaweed) on the coasts of Scotland and France has been carried out for more than a century. The crop was then burned and used as a fertilizer. Like the wood ash industry it was snuffed out by Stasfurt potash in 1861, except in so far as it afforded a source of iodine.

During late years both governmental funds and private capital have been spent lavishly in investigating the possibilities of the Giant Kelps along the Pacific coast. These fields extend from Lower California to Alaska, and it was hoped that they would afford limitless supplies of potash. Most of the reduction plants have been erected in the neighborhood of San Diego, California. Two general processes have been tried, incineration and fermentation. In 1917 the production of potash from kelp amounted to 3575 tons, and in 1918 it did not exceed 9000 tons. The kelp is cut by seagoing dredges, acting like huge mowing machines, transported to land and dumped. It is said that it costs \$1.10 to harvest and dump a ton of seaweed averaging only 1.5 per cent potash, or \$85 per ton of potash brought to land. Under these conditions not much hope can be entertained for the permanent success of an industry that aims to yield potash as a main product by the incineration method.

But much more favorable is the outlook for plants like that of the Hercules Powder Company. That company needed acetone and other organic solvents, and worked out processes for getting them from the fermentation of seaweed. The outlay for apparatus was enormous, and the scale of operations is

immense, but as acetone, oils, esters, organic acids, algin, iodine, salt and potassium compounds are prepared in correspondingly large amounts, there is reason to view this as a permanent industry, and not one to cease with the coming of peace. With large technical staffs and expert sales organizations available, the outlook is favorable.

#### CONCLUSION

And thus we see how Germany's "vaunting ambition doth o'er leap itself" as truly in technical fields as in military and governmental affairs. She had the world buying potash from her mines, and a fleet of merchantmen carrying it to the uttermost parts of the earth. Her customers paid whatever price was demanded, and considered competition hopeless. Then came war, and long preparation for a short, intense campaign—like those waged under Bismarck's direction—gave her an instant advantage over peaceable nations who thought of war in terms of Sherman's definition. Conquest for booty, loot and subjugation of alien peoples—sordid and selfish motives all—was to the Junker and militarist only "big business."

But how she miscalculated the moral, mental and material reserves of an outraged world! Instead of having but one or two antagonists to dispose of at a time, the other nations being cowed into inaction through physical fear, she was soon surrounded by the dreaded wall of blood and iron, a circle of steel, and brought to bay, with a world against her. The eleventh hour of the fateful eleventh day of the eleventh month, 1918, marked the end of actual hostilities. What a reversal of form!

And what a shock it will be to the government-controlled Kalisyndikat to realize that its monopoly has been broken, that America increased its potash production from practically nothing in 1914 to 10,000 tons in 1916, 33,000 tons in 1917, and 65,000 tons in 1918, with the prospect of ever increasing production until all that is needed can come directly from local plants!

America's economic independence of German potash is thus a valuable by-product of this frightful World War, a result entirely unforeseen by friend and foe in 1914. The end has not

been reached without hard work, scientific skill, ample capital, constructive ability and business daring on the part of our citizens, but this victory in an art of peace is no less splendid than that won in war itself. Its story constitutes another chapter in the romance of American industrial achievement.

#### ADDENDUM

Revised statistics issued since the above was written give a somewhat smaller production of potash during 1918 than was estimated in October of that year. Press Bulletin No. 399 (February, 1919) of the United States Geological Survey reads in part as follows:

Statistics of the production of potash in the United States in 1918, which are complete except for reports from some of the smaller producers, show a large increase of output. The returns now at hand indicate a total production of 192,587 short tons of potash materials containing 52,135 short tons of actual potash ( $K_2O$ ). They are summarized in the following tables, compiled by W. B. Hicks, of the United States Geological Survey, Department of the Interior.

*Potash produced in the United States in 1918, classified according to sources*

SOURCES	NUMBER OF PRODUCERS	TOTAL PRODUCTION	AVAILABLE POTASH ( $K_2O$ )
		<i>tons</i>	<i>tons</i>
Natural brines.....	21	147,125	39,255
Alunite.....	4	6,073	2,619
Dust from cement mills.....	9	11,739	1,429
Kelp .....	6	14,456	4,292
Molasses distillery waste.....	4	9,505	3,322
Steffens waste water .....	5	2,818	761
Wood ashes.....	26	609	365
Other sources.....	3	262	92
Total.....	78	192,587	52,135

The production in 1918 was almost double that in 1917. About 75 per cent of the total output came from natural brines, 55 per cent coming from brines in Nebraska alone. Most of the product was in the form of mixed salts and fertilizer materials containing from 20 to 30

per cent of potash ( $K_2O$ ). About 24 per cent of it was in the form of muriate and about 6 per cent in the form of sulphate.

For several years immediately before the European war the United States used annually an average of about 240,000 short tons of actual potash ( $K_2O$ ). The production so far reported in 1918 is therefore about 22 per cent of our normal consumption. The imports during 1918 were very small. The producers reported that on January 1, 1919, they had in storage 60,426 tons of crude potash, held because of the dull market prevailing during the latter part of 1918. These figures represent a minimum, as some producers did not give quantities, but stated that they had produced considerably in excess of sales. Most of the potash now held in storage was produced when the price was high, when quantity production was the main object, and when competition with foreign potash was not considered. The price now offered for that material is apparently below the actual cost at which many firms produced it, consequently there is a crisis in the domestic potash industry. Many producing plants have already shut down, and others are marking time.

The producing capacity of American potash plants, classified according to sources of raw materials, is estimated roughly as follows:

*Capacity of American potash plants*

SOURCE	AVAILABLE POTASH ( $K_2O$ )
	<i>tons</i>
Natural brines	
Nebraska lakes .....	50,000
Other sources .....	28,000
Alunite .....	4,000
Dust from cement mills .....	3,500
Kelp .....	5,500
Molasses distillery waste .....	4,000
Steffens waste water .....	3,000
Wood ashes .....	1,000
Other sources .....	1,000
Total .....	100,000

This quantity corresponds to more than 40 per cent of our normal consumption and indicates what may be produced in the United States during 1919 provided the American producers are able to compete with foreign producers.

It is evident that plants extracting potash from kelp were among the first to shut down after the signing of the armistice, and that many contemplated enterprises were allowed to die. Offsetting these abandoned projects in part at least, it should be noted that plants for making potassium chloride and sulphate from leucite are now operating.

## THE USE OF OUTLINE CHARTS IN TEACHING VERTEBRATE PALEONTOLOGY

MAURICE G. MEHL

It is undoubtedly the common experience of all teachers of vertebrate paleontology and comparative osteology that only those anatomical structures or relations presented to the student through visual instruction become a part of his real working store of knowledge. Occasionally the exceptional teacher is able to fix uninteresting facts in the student's mind by means of fitting illustrations, fascinating stories, or accounts of first hand experiences. Certain it is, however, that only in proportion as the student visualizes a structure is he able to retain it. For this reason the teacher of paleontology usually feels very keenly the need of a large supply of museum or laboratory materials; mounted skeletons, skeletal parts, drawings, charts, transparencies, etc.

There are few colleges or universities that have an adequate supply of skeletal material for teaching vertebrate paleontology to the best advantage. Even so, much of the material available is not entirely safe in the hands of the inexperienced student. As a rule the lack of space, the cost involved, or the fact that collections are built up but slowly and many specimens cannot be duplicated, holds the collections down to a few illustrative types. Each institution is inclined to specialize in, to over emphasize, perhaps, the group or groups which are most available to it, and for illustrative material in other groups the student is forced to depend on written or oral descriptions and drawings. Were one able to study in several institutions till the entire field had been covered this would constitute ideal instruction, to be sure, but this is impossible in many cases.

It was because of a lack of skeletal parts by means of which the student could become thoroughly acquainted with the struc-

tures illustrating the main types of vertebrates that the writer was led in an attempt to supply the materials by means of charts. It was recognized that even when certain structures were well described, such illustrations as were available were often inadequate and gave the student little more than an idea of the shape of the bones. Even to gain this it was usually necessary to work through a great mass of literature, often not available. To work out a chart for each form or group with which it was desired to become familiar would mean an endless task. Furthermore, such charts would not have the vital interest which the preparator gains as he "works out" and mounts a skeleton. It was thought that could the student be furnished with a set of conventional "paper bones" from which he could construct skeletons at will, much of the difficulty of teaching the vertebrate skeleton would be eliminated.

Some time ago the writer conceived the idea of compiling a guide chart on which were designated the elements in the primitive skull together with the conspicuous openings in their proper relations. Working on the principle that organic evolution involves only the loss of parts or the modification of existing elements, the student was expected to construct any skull from the base by discarding or utilizing the lines bounding the primitive elements.

The results of this experiment were very gratifying. While the guide chart had been compiled for the sole purpose of supplying laboratory materials, it was found that it answered other purposes as well. In the first place the student came to realize that it was the elements and openings and their relations in the skull that were all important; the size and shape were of secondary consideration. The use of the same size and shape of skull to show the structure of various types seemed to give a new meaning to the word "structure": the student observed that between the largest and the smallest dinosaur skulls there were fewer differences than between many skulls that in a hasty glance seemed very similar.

Again, he came to a realization, as never before, that every form, no matter how complicated, was merely a modification,

through loss chiefly, of a pre-existing, more generalized type, a fact strikingly presented by the discarded parts that accompany every "finished" skull.

Not least of the advantages of the guide charts was the manner in which they assisted the student to become familiar with the technical terms. After he has worked out several types and labeled each element, every name comes to have a rather definite meaning.

Encouraged with the results gained from the use of the chart for the skull and at the suggestion of the late Dr. S. W. Williston, the writer attempted the compilation of guide charts for the limbs and the vertebrae. These guide charts, together with some suggestions as to their use are presented herewith.

#### THE SKULL

The chart for the skull, plate IX, consists of dorsal, ventral, and posterior views. It is accompanied by a form suitable for student use in the laboratory. While the chart was designed primarily to illustrate the amphibians and reptiles, it may be used for the mammals and birds. The solid lines mark the outlines of the skull and the openings commonly present such as the orbits and nares. It is only in exceptional cases, for instance, to close the otic notch, that these lines should be modified.

In the dorsal view the elements found in the primitive skull are outlined by dots. Each bone in the type to be represented should be designated by following its dotted outlines with heavy, preferably red, lines. When an element or elements are missing, the outlines are ignored and the adjacent bones are expanded in the proper directions to fill the space and maintain the proper relations. In the exclusion of the lacrimal from the nares and in other rare instances, the dotted lines will necessarily be changed slightly.

In the ventral view the same plan is followed as in the dorsal. The dotted lines give a choice between a single and a double occipital condyle. A large and small interpterygoid vacuity are designated by dashed outlines and a dotted line from the

anterior end of each gives a choice between a large and small parasphenoid. It will be found that with the use of the small vacuity and small parasphenoid, the sutures between the palatines, pterygoids, and vomers will have to be slightly modified.

A false palate may be indicated by adding a line drawn across the bones of the palate along points at which the fold takes place. Arrows pointing from this line to the median line of the skull indicate the fold somewhat more effectively.

Teeth on the various elements may be designated by circles or crosses. The various types, thecodont, acrodont, etc., may be designated by special symbols agreed upon.

The posterior view gives a choice between a single and double occipital condyle. When the single condyle is utilized the outline remains unchanged. The suture between the tabular and the paroccipital is left incomplete so that it may be continued toward the median line of the skull in any direction so as to maintain the desired relations between the supraoccipital and the laterally adjacent bones.

An index sheet, plate VIII, furnishes the names in common use for the various bones of the skull. Most of the openings are indicated in a like manner. To eliminate confusion, openings are indicated by a curved line beneath the abbreviation for the name. Unpaired bones are underscored with a straight line. In filling out a chart the same abbreviations should be used as are given in the index sheet, and the openings and unpaired bones should be designated in the same manner.

#### THE LIMBS

The guide chart for the limbs, plate X, furnishes outlines for both the front and the hind legs. Names of the various elements should be added by the student. All of the elements in the primitive leg are represented by conventional designs save in the case of the mesopodials. Here there is so much doubt as to the primitive arrangement and number, and such a variation among known forms, that only the lines to designate the three rows are given. Between these, vertical lines may be drawn to

indicate the number and relative proportions of the bones in each row. The loss of all or a part of the ulna or fibula may be shown by ignoring the outlines of these bones or by using only

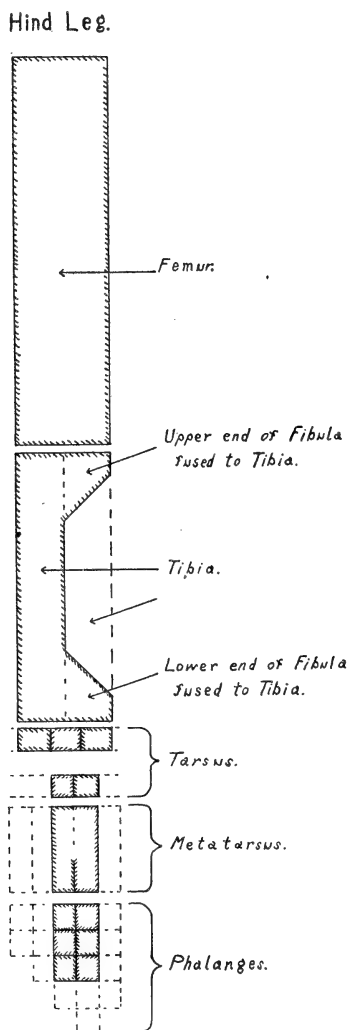


FIG. 1

those lines bounding the part retained. The fusion of two bones is indicated by omitting the division between them. In the humerus the presence of the ectepicondylar or entepicondylar

foramen is indicated by following the dotted circles near the distal end of this bone. These foramina may be further emphasized by placing a cross within the circle. A hyperphalangate or hyperdactylate condition in the hand or foot may be indicated either by the addition of new squares or the splitting of the present rectangles by vertical or horizontal lines or both.

The accompanying diagram, figure 1, shows how the completed chart for a purely hypothetical form might appear. The features indicated are the loss of the shaft portion of the fibula and the fusion of the upper and lower ends of this bone with the tibia; the loss of the first, second, and fifth metatarsals and the partial fusion of the third and fourth; and the loss of all the phalanges in the first, second, and fifth fingers and the loss of one and two phalanges in the third and fourth fingers respectively. In the tarsus there are but two rows of bones with three elements in the proximal and two in the distal row.

#### THE VERTEBRAE

While the guide chart for the composition and modification of the vertebrae, plate XI, is not all that could be desired for certain primitive forms, it works well for the great majority of types. The names of the parts should be added by the student.

In the end view given in this chart a perforate or solid centrum may be shown. The upper set of dotted angles near the neural canal is used to show the presence of the zygosphenes and the lower set is for the hyposphenes. While the lateral view shows the presence or absence of the hypocentrum and its relative size, it is also shown in the end view where it may be designated as a single unit or composed of two parts.

In the lateral view the composition and modification of the centrum may be more fully shown. Temnospondylous types as illustrated by *Cricotus* and *Eryops* may be shown by utilizing certain of the dotted lines while holospondylous forms are indicated by ignoring these. The presence of an intercentrum is indicated by following another dotted line that cuts off a small triangular space in the lower anterior corner of the out-

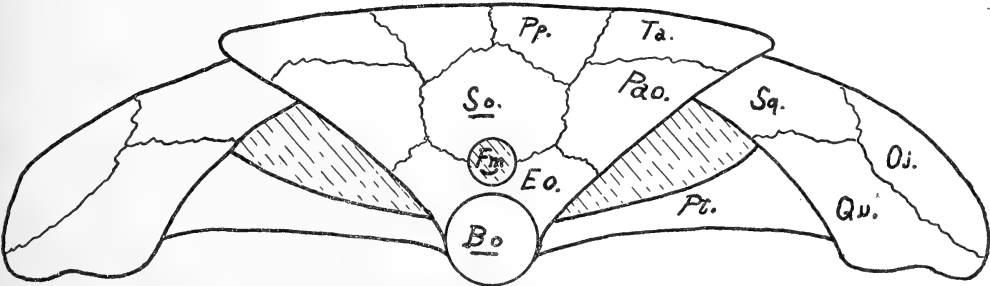
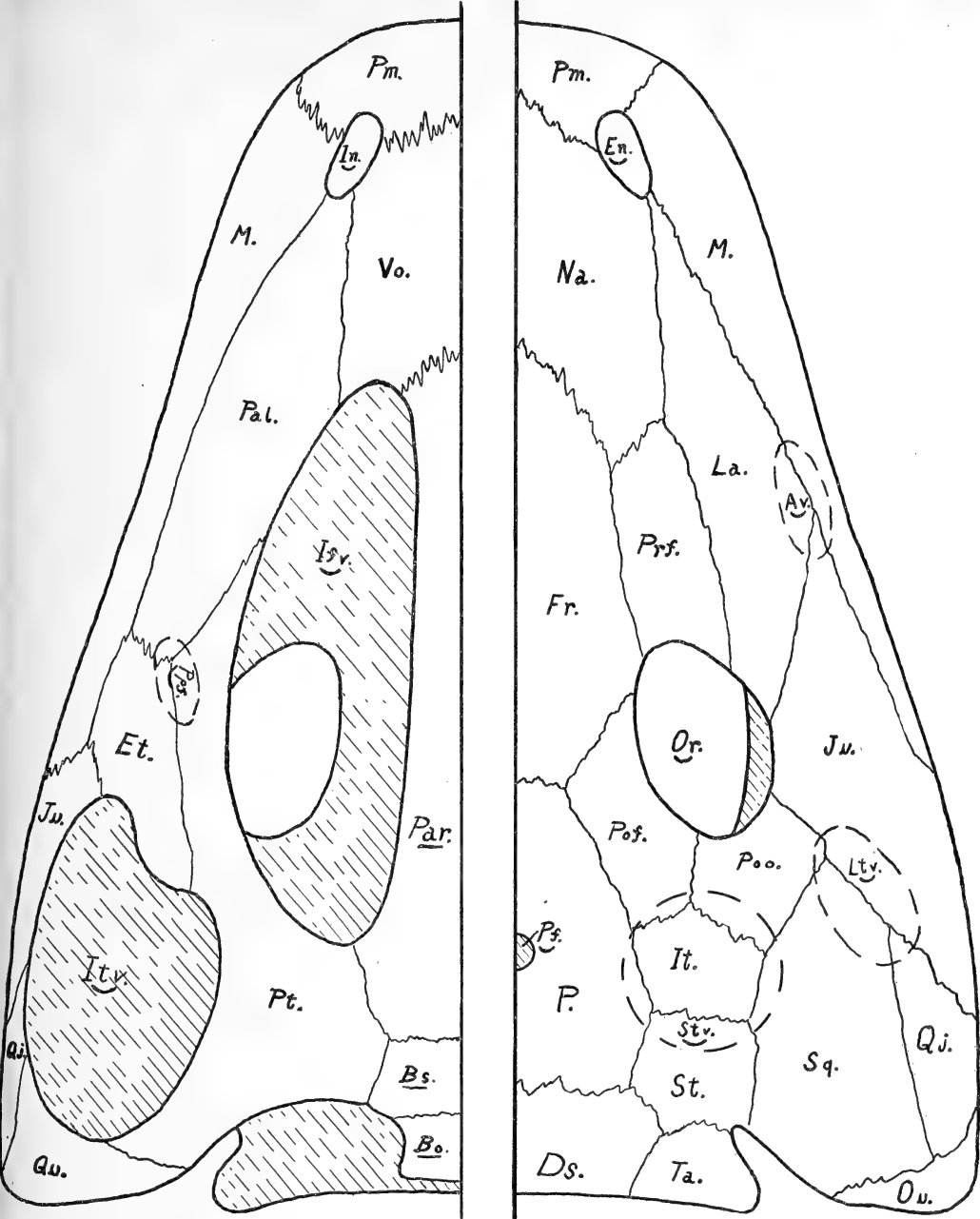
line of the centrum. For amphiplatyan vertebrae the lines at the ends of the centrum are not altered, but for procoelous, opisthocoelous, and amphicoelous types the suitable curved dotted lines are to be used. It has been found useful to outline the several elements composing the vertebrae with hachures as is shown in the illustration of foot structure (fig. 1).

The importance of the rib articulation has long been recognized. No two animals with different rib articulations can be closely related. For this reason the facets on the vertebrae should be carefully noted. In the lateral view of the vertebra the small dotted circles permit the designation of all possible rib attachments. For a double, diapophysial attachment a cross should be placed in each of the two circles on the diapophysis. Obviously the small half circles at the posterior end of the centrum are used to indicate intervertebral attachments.

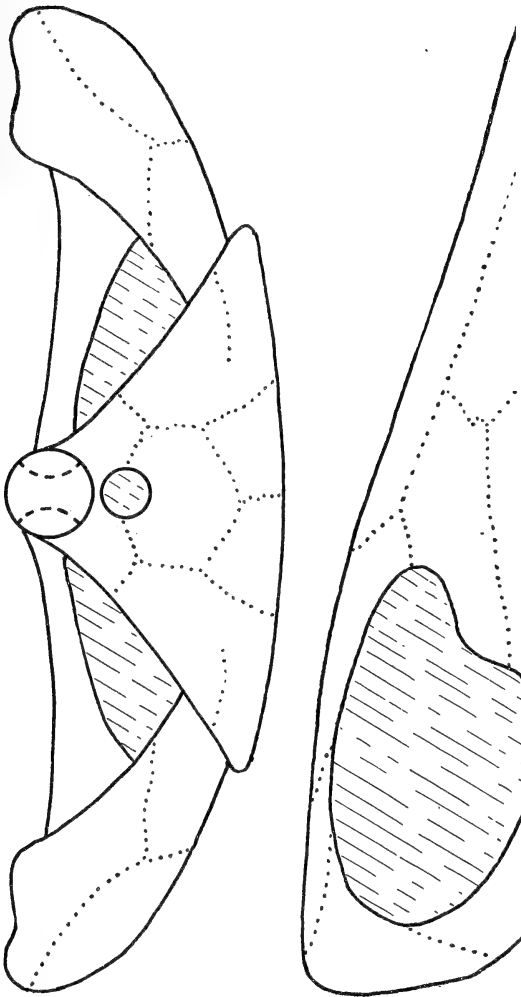
No doubt the guide charts as here presented are inadequate in many respects and not unlikely will they be found to contain certain errors. Other uses of the charts may suggest themselves and perhaps other forms may be added. The writer has tried forms for showing the structure of the pectoral and pelvic girdles and also a form for showing the evolution of the teeth. In both of these cases, however, the results were of doubtful benefit because of the complexity of the charts.

# PLATE VIII

Av, antorbital vacuity	Pal, palatine
Bo, basioccipital	Pao, paroccipital (opisthotic)
Bs, basisphenoid	Par, parasphenoid
En, external nares	Pf, parietal foramen
Eo, exoccipital	Pm, premaxilla
Et, ectopterygoid (transverse)	Po, postfrontal
Ds, dermosupraoccipital (postparietal)	Poo, postorbital
Fm, foramen magnum	Ppf, postpalatine foramen
Fr, frontal	Prf, prefrontal
In, internal nares	Pt, pterygoid
Ipv, interpterygoid vacuity	Qj, quadratojugal
It, intertemporal	Qu, quadrate
Itv, intertemporal vacuity	So, supraoccipital
Ju, jugal	Sq, squamosal
La, lacrimal	St, supratemporal
Ltv, lateral temporal fenestra	Stv, supratemporal vacuity
M, maxilla	Ta, tabular
Na, nasal	Vo, vomer
Or, orbit	⌋ an opening
P, parietal	— an unpaired bone



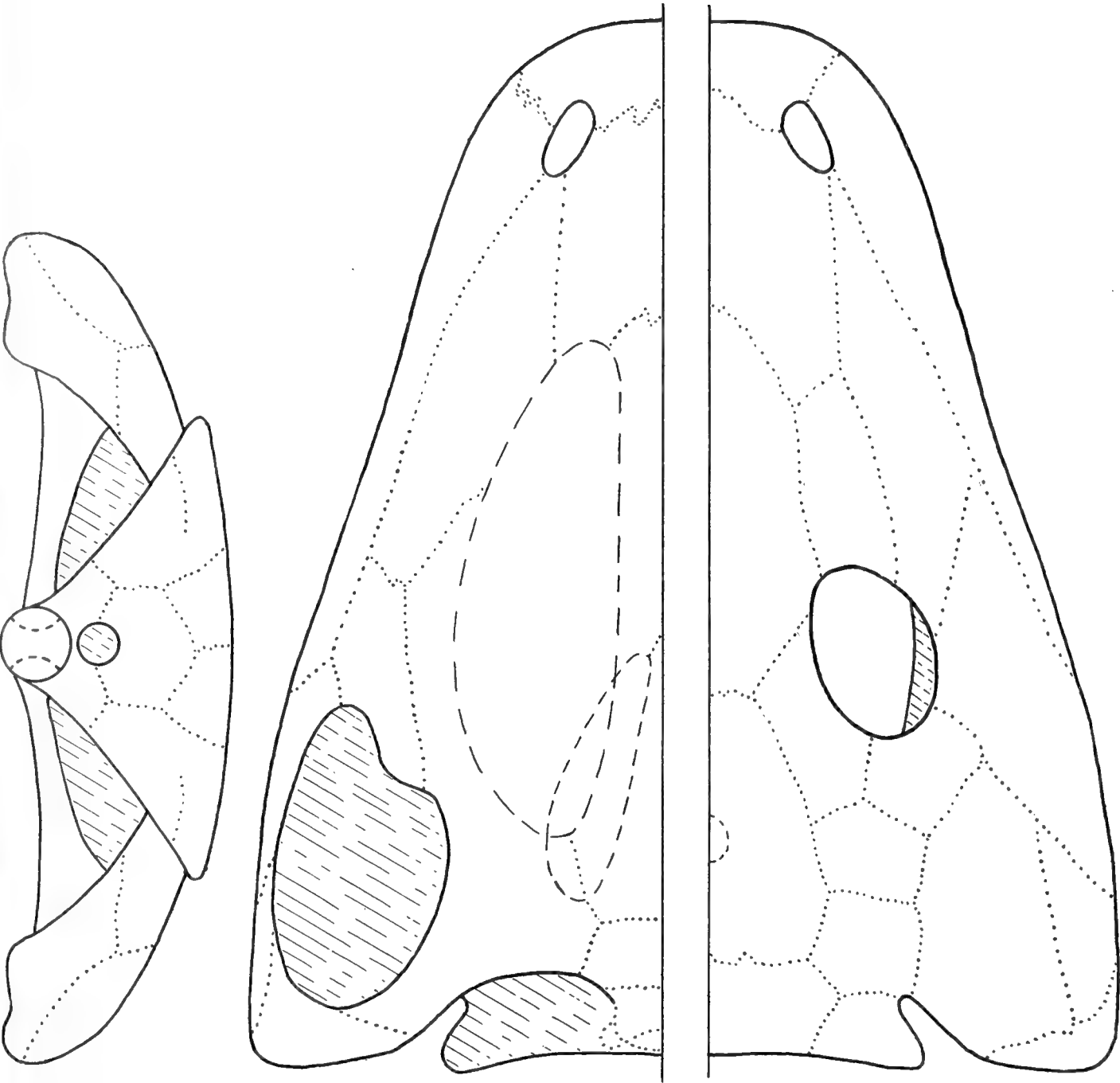




M. G. MEHL: OUTLINE CHARTS VERTEBRATE PALEONTOLOGY

Subject.....  
Name.....  
References.....  
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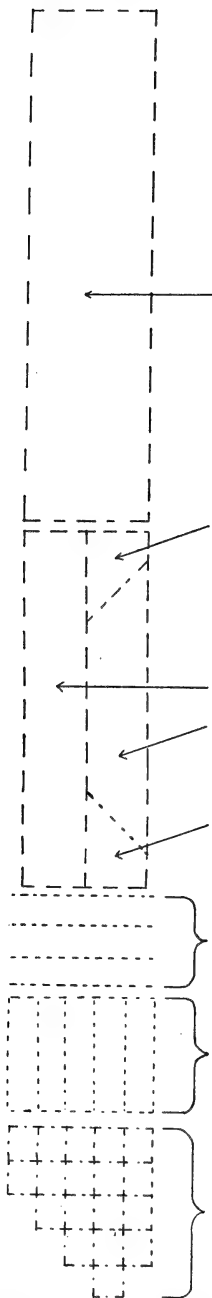
THE SKULL

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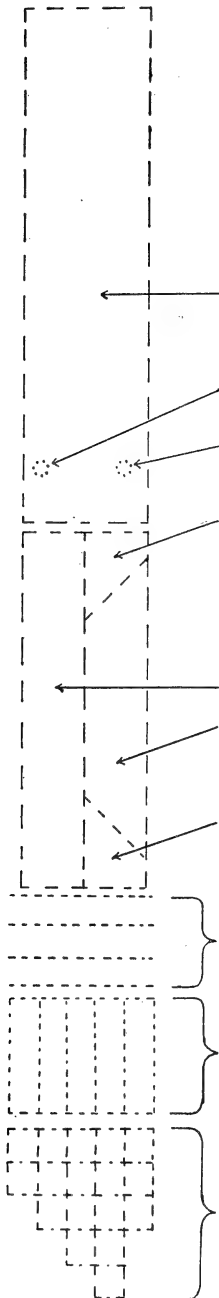
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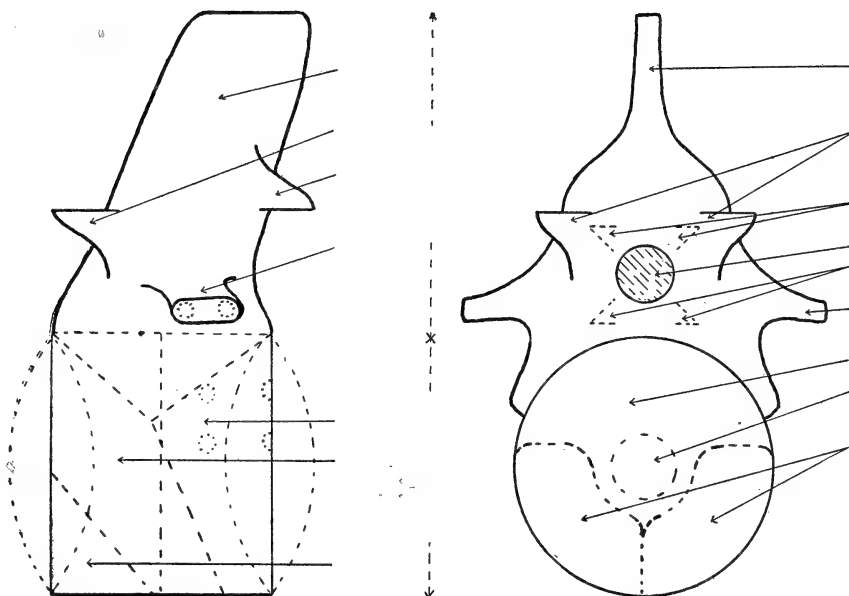


Hind Leg.



Front Leg.





## SOME FACTORS IN THE GEOGRAPHIC DISTRIBUTION OF PETROLEUM

MAURICE G. MEHL

Few industries have experienced such rapid or so comprehensive development as has the petroleum industry. The use of petroleum and its products is so firmly fixed in the affairs of man and so important are these products to his activities of industry and pleasure that even a slight reduction in the petroleum output would probably work real hardships on a large proportion of the human race. The discovery of new areas of accumulation of petroleum and the rapid development of these new fields have followed each other in rapid succession during the past few years. Production, nevertheless, scarcely keeps pace with the growing demands.

Some look with alarm on the rate of consumption of our known supply of petroleum and many are already studying the possibilities of new stores from other sources or other regions. Not a few of the larger corporations are sending representatives from time to time to investigate the possibilities in unexplored or inadequately tested parts of the world.

Whether an actual shortage faces us at some near date or not, certain it is that at some future time it will be necessary, or at least desirable, to determine what may be expected in the way of a world supply of petroleum. When prospecting is carried into regions of unknown possibilities, to countries not now important as producers of petroleum, what is to be the guide; what shall determine the order in which the various "possible" regions are to be investigated? Just as today experts are able to designate the most favorable places for testing a given region, will it not be possible in the future to indicate, within the confines of well founded theory, at least, a logical order in which the land masses of the earth should be tested?

In the following paragraphs the writer attempts to correlate certain facts and observations which may assist in the solution of some of the problems in the geographic distribution of petroleum. There is no attempt at exhaustive treatment and little or no claim is made for originality. It is hoped that the speculations will call forth a discussion of the principles involved and possibly stimulate investigations in the several branches of science interested. It is only through the coöperation of the experts in these sciences that adequately supported conclusions as to the likely distribution of petroleum can be reached.

Considering petroleum and the related substances as a group, they are among the most widely distributed minerals; there are but few unmetamorphosed sedimentary beds that contain no trace of these hydrocarbons. Small showings are found encircling the globe and they extend from well toward the poles to the equator. Workable accumulations are much less widely distributed, however, and great commercial deposits are comparatively rare.

On the accompanying map, plate XII, are platted the more important areas of production throughout the world. It will be noted at once that these major accumulations, as they may be termed, are confined to the northern hemisphere. It will also be seen that none of the areas indicated extend north of  $50^{\circ}$  N. latitude nor south of  $20^{\circ}$  N. latitude. In fact, if one is to avoid extremely sinuous lines, perhaps no better boundary could be desired than these parallels.

True, outside of this belt are known deposits of some magnitude, accumulations that might be classed with the major fields, such, for example, as those of Alaska, Peru, or Ecuador. These and other possible exceptions, however, are in no wise comparable with the productive areas about the Black and Caspian Seas, the Lorraine district, the great belt across the United States, or the accumulations in Mexico.

Attention is further called to the general correspondence between the position of the twentieth and fiftieth parallels in both hemispheres with the average annual isotherms of  $70^{\circ}$  and  $40^{\circ}$  respectively. Although these parallels are, in reality, nothing

more than imaginary lines of geographic reference, each does, in much probability, mark the average position of some isotherm as it has shifted in past geological times. While the disposition of maximum accumulations as here bounded does not indicate a definite temperature zone within which petroleum has been formed, it does suggest a distinctly zonal distribution of petroleum in which temperature may have been an important factor.

At once the question arises as to whether these apparent boundaries of the zone of maximum accumulations fit well with the actual conditions or whether further investigation will greatly modify the shape and extent of the "important" areas. If there is this actual zonal distribution of petroleum, one must consider several factors involved in such limitation and with these speculations others follow such as the possibility of a "barren" equatorial belt and a productive zone in the southern hemisphere corresponding with that of the northern.

There is, of course, grave danger in assuming that the belt of maximum production is as observed, or that such an area may be expected to have anything in the way of a definite boundary, even theoretically. There can be little doubt, for instance, that this zone has offered the most favorable conditions for exploration and it is not unlikely that with more extensive prospecting other great accumulations of petroleum will be found, possibly well outside these approximate boundaries.

Regardless of the lack of thorough prospecting, however, there is reason to believe that of the three zones, the equatorial belt between the twentieth parallels and adjacent belts in the northern and southern hemispheres extending north and south to the fiftieth parallels, the northern belt will, when investigations are carried to completion, be found the more productive. For instance, one may safely assert that, all other factors being equal, the amount of petroleum underlying a given area is directly proportional to the size of that area. It is evident that in the area of exposed lands neither the southern nor the equatorial belts compare favorably with the northern zone.

Inasmuch as important accumulations of petroleum in Pre-Cambrian rocks are unknown, certain broad areas of Pre-Cam-

brian and igneous rocks may at once be designated as impossible territory. The proportion of the possible productive territory to the total area in each zone differs greatly. Again the differences favor the northern zone for the proportion of the Post-Cambrian area to the total land surface is much greater in this belt (see plate XIII). Furthermore, the "possible" territory in the other zones includes considerable areas that may properly be eliminated because of the presence of sediments representing periods that are generally barren throughout the world, such as the broad expanse of supposed Triassic rocks in northeastern South America and the great areas of Mesozoics in eastern Australia and central Africa.

The foregoing considerations are all, in a sense, passive agents, factors which would tend to minimize the importance of petroleum accumulations outside of the northern belt. So closely confined to this belt are the great accumulations as they are known today that it is thought there must be a more active determining factor; one of the fundamental influences in the formation of petroleum. Of these, one of the most far reaching is probably the temperature consideration.

It may safely be granted, perhaps, that petroleum is derived from organic matter. Without going into the evidence it may also be stated that there is reason for assuming that no particular group or groups of organisms may be designated as the source of petroleum except that all evidence points to the fact that it is only the smaller plants and animals, perhaps largely the microscopic forms, and fragmental material from larger organisms that are available.

It is evident that there is a marked dependence of life on temperature conditions. Perhaps this one factor, more than any other, determines the variety and abundance of life throughout the world. It is recognized that the amount of agitation of the waters, the degree of salinity, the nature and amount of sediment, the depth of the water, etc., are very important factors in the distribution of marine life, but for every temperature these other conditions may be found in almost endless variety and combination. Still, life is not equally abundant in every

temperature. While it is true that there is more or less of a "patchwork" arrangement of temperatures in the ocean, cold waters often immediately adjacent to warm waters, it may be said in general that the temperature increases toward the equator. Likewise, with conspicuous exceptions, the abundance and variety of life increases rapidly toward the equator. So far as the abundance of life alone is concerned, it seems likely that there has been some limit, poleward from which the formation of petroleum has been of little importance.

Other factors concerned in the origin of petroleum from organisms have been suggested, factors of equal or greater importance than the relative amount of organic matter available. Two of the most conspicuous of these is the rate of decay of organic matter and the rate of sedimentation. A brief consideration of some of the principles involved will make the importance of these factors more evident.

Many sorts of organisms have been subjected to destructive distillation in an attempt to produce petroleum. Of these substances a large number, both plant and animal and various combinations, have produced oils very similar to natural petroleum. It has been noted in all cases, however, that it is the fatty portion of the organism that produces the desired results. In every case where the entire organism is utilized the simulation of petroleum is much less marked, especially in the presence of large proportions of nitrogenous bases in the synthetic product. Apparently in nature there has been a very efficient denitrifying agent coöperating in the formation of petroleum.

As such a denitrifying agent, nothing more adequate, more logical is suggested than denitrifying bacteria. While the abundance, the importance, and the exact rôle of these organisms is not generally understood, the principles involved are evident. Apparently their first activity in the destruction of organic matter is the consumption of the nitrogenous portions; the fatty parts are for a time untouched. In the decay of a given amount of organic detritus, up to a certain time, there is an actual increase in the proportion of fatty material to the whole.

The destruction of organic matter by denitrifying bacteria is not confined to the nitrogenous portions alone, however; in time the fats are also attacked and, in the normal process of decay, these too are entirely destroyed. Obviously, other factors being equal, in those regions in which denitrifying bacteria are most active the destruction of the fatty portions of organisms should be fastest and most complete; there should be the least likelihood of the formation of petroleum. For ideal conditions in the formation of petroleum the denitrifying bacteria should be sufficiently active to denitrify the organic base, but their abundance should not make possible the excessive destruction of the fatty portions.

Vaughan has pointed out the part played by denitrifying bacteria in the precipitation of calcium carbonate from sea water and has stated that this activity, if not confined to tropical waters, is at least most marked in the warmer portions of the sea.<sup>1</sup> Drew, in speaking of *Bacterium calcis* and other denitrifying bacteria, says:<sup>2</sup>

Such action would be almost limited to comparatively shallow seas whose temperature approximated to that of tropical seas at the present time.

Now, while such investigations offer no conclusive evidence as to whether denitrifying bacteria are sufficiently active to effectively destroy the fatty portions of decaying organic matter in the equatorial belt, they do indicate that the destruction would be progressively greater toward the equator, other factors being equal. From this standpoint it does not seem unlikely that throughout past times there have been fluctuating boundaries beyond which, toward the equator, conditions for the formation of petroleum have been subnormal.

<sup>1</sup> Vaughan, T. W., Preliminary remarks on the Bahamas, with special reference to the origin of the Bahaman and Floridian oolite: Carnegie Inst. Washington, Pub. no. 182, pp. 47-54, 1914.

<sup>2</sup> Drew, G. H., On the precipitation of calcium carbonate in the sea by marine bacteria, and on the action of denitrifying bacteria in tropical and temperate seas: Carnegie Inst. Washington, Pub. no. 182, pp. 7-45, 1914.

While the importance of the temperature check on the activities of denitrifying bacteria has been indicated, it is obvious that there must be a check of another sort as well. In any region where the bacteria are sufficiently active to denitrify the organic base of petroleum more or less completely, the fats would also be destroyed were such a check not operative.

It has been assumed by some writers that the formation of petroleum would in itself constitute an automatic check on bacterial destruction by virtue of antiseptic products. This is not in keeping with the observed processes of decay, however, and it assumes, furthermore, that petroleum is formed almost, if not quite, as rapidly as the nitrogenous bases are destroyed. As a matter of fact, all evidence points to an opposite condition, the extreme slowness with which petroleum is formed. It is, perhaps, not far from correct to assume that the hydrocarbon substance in oil shales is the somewhat altered organic base which, after the lapse of an extremely great length of time, has not yet been transformed into the ultimate product, petroleum. It is only by hastening the process through destructive distillation that petroleum may be derived from these shales.

There is, apparently, a check of a mechanical nature found in the accumulation of inorganic sediments. It is generally recognized that accumulations of soil and fine sediment materially limit the activities of bacteria. It follows that the more rapid the deposition of fine sediments, the more complete the check. In much probability the fineness of the sediments has been one of the most important of the factors determining the rock associations of petroleum. At any rate, petroleum is associated primarily with shales. The presence of nitrogen in varying proportions in petroleum would seem to testify to the effectiveness of the shales as a check on the destruction of organic matter on occasion. In the cases of marked proportions of nitrogen we may suppose, perhaps, that not only have the fatty portions of the original base been protected, but that not even all of the nitrogenous parts have been destroyed by bacterial activities.

It may be assumed that in general the rate of sedimentation is slower in the equatorial belt than elsewhere, a fact evidenced

by the thick accumulations of soil on these lands. Again, from the standpoint of the inadequacy of the check on the destruction of the fatty base by bacteria, the equatorial belt should be less favored in accumulations of petroleum. This too is largely a function of temperature, for the slow rate of sedimentation is in no small measure due to the luxuriant growth of vegetation which prevents the free wash of the rock waste from the land.

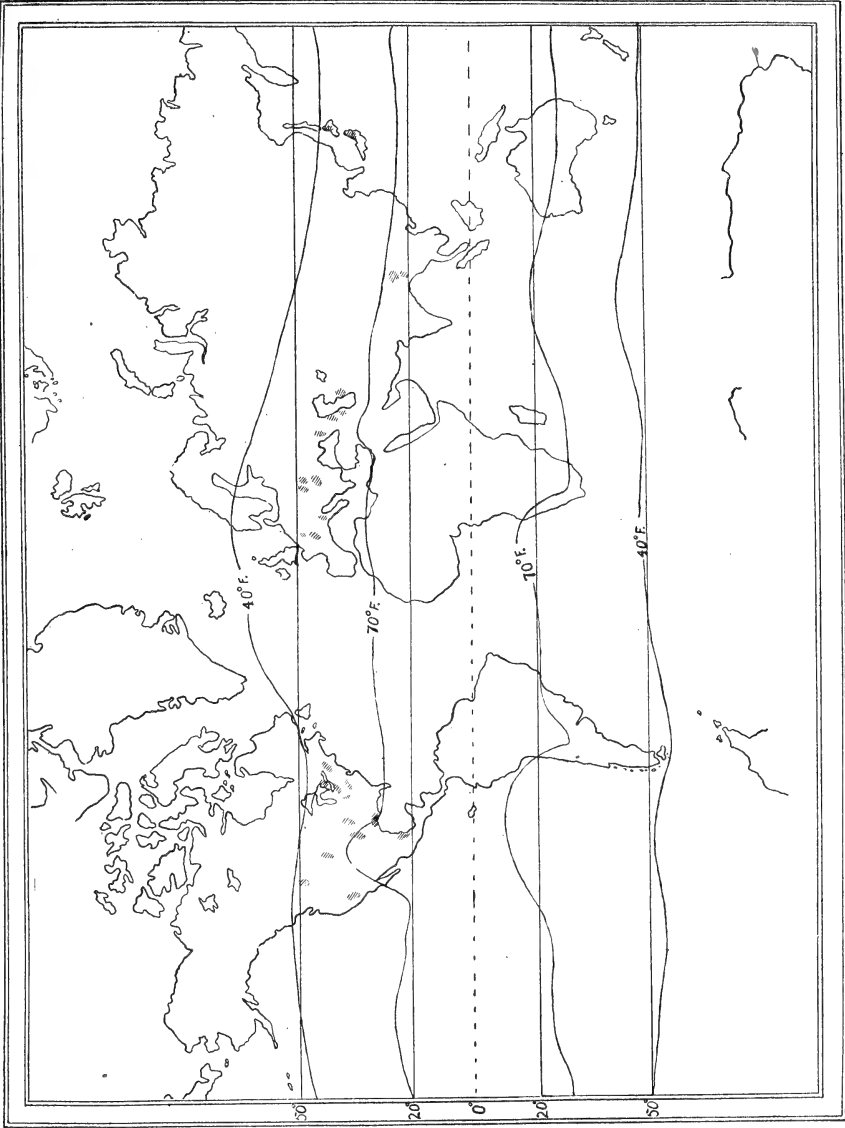
Aside from its function as a check to the activities of denitrifying bacteria, the rate of accumulation of inorganic sediments is of further importance in the formation of petroleum. Very often the rapid decay of organisms is pointed to as illustrating the manner in which petroleum is formed. In certain parts of the Mediterranean Sea, for instance, the accumulation and decay of organic detritus is so rapid that the lower levels of the water are filled with scattered globules of oil. Instead of illustrating how petroleum is formed, however, it points to the effective manner in which fatty matter is ordinarily separated out from accumulating sediments. Certainly, the globules of oil which are escaping into the water offer no suggestion of being retrapped and converted into petroleum. It is only that part of the organic matter which is converted into oil so slowly that the accumulating sediments form a sufficient thickness and suitable succession to retain it against the tendency of the associated waters to drive it off, that may become petroleum.

If we may grant, then, that within a limited zone, the equatorial belt, conditions have been unfavorable for the formation of accumulations of petroleum, on the average, it is logical to seek a belt in the southern hemisphere suitable for such deposits, to correspond with the belt in the northern hemisphere. Were the temperature factors alone to be considered, there is little doubt but that much might be expected from the southern zone. It has already been pointed out, however, that the area of exposed land within this zone is relatively small and of this a very large proportion consists of Pre-Cambrian or igneous rocks. Apparently little more is to be expected from the southern belt than from the equatorial zone.

Now, while in the foregoing paragraphs certain considerations have been presented which point to the maximum petroleum accumulations in a zone between the twentieth and fiftieth parallels in the northern hemisphere, it would be a grave error to assume that nothing is to be gained by prospecting outside of this belt. Even if later investigations should show the speculations here presented to be well founded, it would seem in keeping with the theories advanced that there should occasionally be found within the very heart of the equatorial belt, accumulations of importance. As a working hypothesis only, it is suggested that the prospector's efforts will much more likely be rewarded in the northern than in the southern belt and that he is least likely to achieve the desired results in the equatorial zone.

## PLATE XII

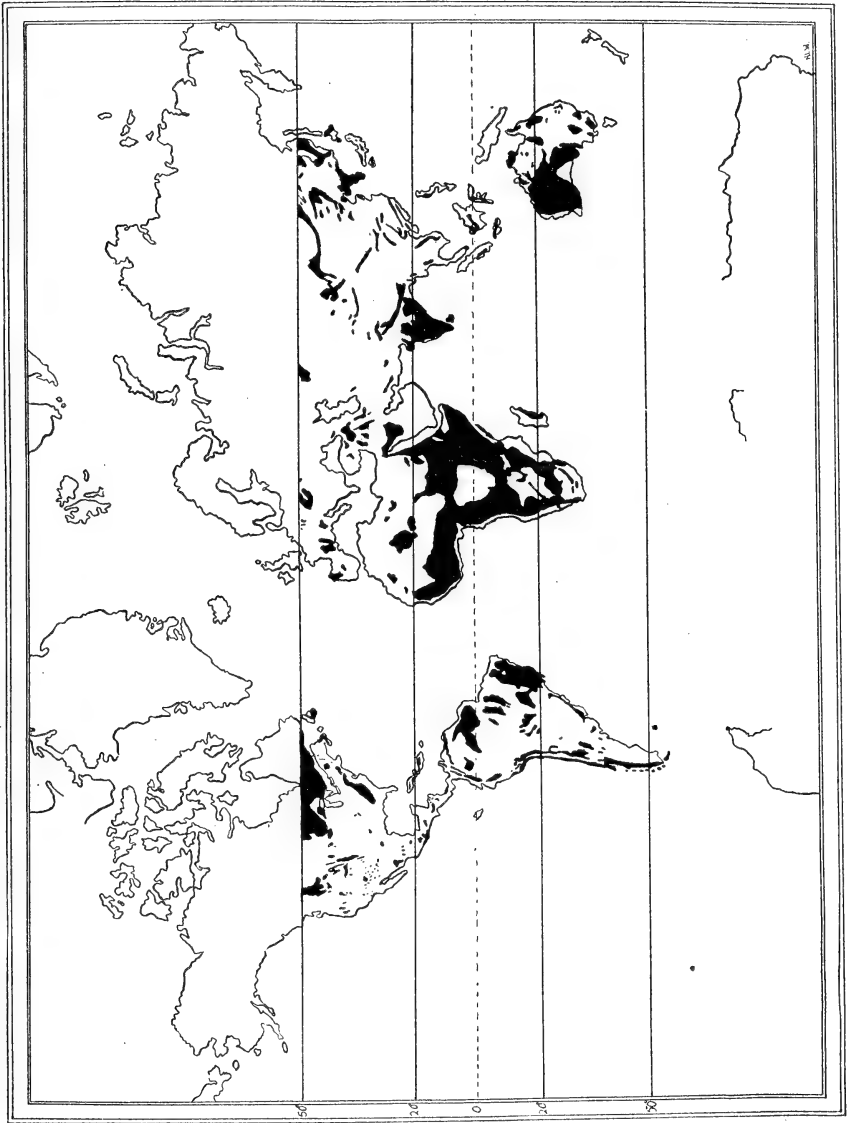
The geographic distribution of petroleum. The known accumulations of petroleum of major importance are indicated by oblique lines. The size of many of the areas is greatly exaggerated and the locations are only approximate.



M. G. MEHL: GEOGRAPHIC DISTRIBUTION OF PETROLEUM

### PLATE XIII

The distribution of Pre-Cambrian and igneous rocks within the equatorial and adjacent belts. The black portions represent the chief areas of Pre-Cambrian sedimentaries or igneous rocks of any age. Areas concerning which no information is available are not differentiated from Post-Proterozoic sedimentaries.



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# BULLETIN

OF THE

## SCIENTIFIC LABORATORIES

OF

### DENISON UNIVERSITY



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## OF THE

### SCIENTIFIC LABORATORIES

## OF

# DENISON UNIVERSITY

Edited by

KIRTLEY F. MATHER

Permanent Secretary, Denison Scientific Association,  
Granville, Ohio

The entire file of volumes 1 to 13 was destroyed by fire; no publications issued prior to 1907 are now available. Volumes 14 to date may be obtained from the editor at \$2.00 per volume, with the exception of volume 15, the price of which is \$1.00. Separate parts, as listed below, may be purchased at the prices indicated.

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## NOTES ON ISOTELUS, ACROLICHAS, CALYMENE, AND ENCRINURUS

AUG. F. FOERSTE

The exact correlation of strata by means of fossils requires an equally exact discrimination of these fossils into species and varieties. Especially is this true of genera in which many of the species are closely related. In the genus *Calymene*, for instance, almost any Ordovician species has been called *C. senaria*, while almost any Niagaran species has been called *C. niagarensis*. Recently Raymond (Bull. Mus. Comp. Zoology, Harvard Univ., 60, 1, 1916, p. 27) has placed the Niagaran species on a better footing. In a similar manner, the various species in the Cincinnati strata of Ohio, Indiana, and Kentucky need more exact discrimination. Very little has been published on the species of *Isotelus* in the Cincinnati strata. Moreover, the published figure of *Encrinurus ornatus* was altogether insufficient for purposes of discrimination from closely similar forms found in other strata. The following pages are intended as a contribution to a more exact discrimination of some of the closely similar forms of the genera mentioned above.

***Isotelus brachycephalus* sp. nov.**

*Plates XIV, XIVA, and XV*

Cephalon (plate XIV) 10.5 cm. in length along its median line, and 26.3 cm. in width at the genal angles; the ratio of the length to the width being four-tenths. The marginal border is depressed or concave for a width varying from 13 mm. anteriorly to nearly 20 mm. along the free cheeks. The facial suture is outlined distinctly both anteriorly and posteriorly to the palpebral lobes, and the position of these lobes is indicated, but the course of the suture along the margin of the palpebral lobes can

not be determined with certainty. Anteriorly the facial sutures are almost marginal, being only 0.5 mm. distant from the anterior margin of the cephalon. They almost meet the anterior margin of the cephalon, at points about 37 mm. on each side of its median line. The length of the genal spines is not known, but, judging from the width of their proximal ends, the tip of these spines must have extended at least as far as the posterior margin of the fourth segment of the thorax.

The length of the thorax (plates XIV and XIVA) along its median line is 12.5 cm.; and its width is about 25.3 cm. There are eight segments, as in other species of *Isotelus* in their adult state. The width of the axial lobe is 10 cm. The broad median groove along the proximal half of the pleural segments, and the diagonal ridge crossing their more distal parts, are as in other species of *Isotelus*.

The posterior end of the pygidium (plate XIVA) is not preserved, but its length is estimated at 13.8 cm., measuring from the posterior margin of the thorax; its width is 24.8 cm.; the ratio of the length to the width being about 55 per cent. Along the antero-lateral angles the surface inclines abruptly downward, forming a low ridge, posterior to which, proximally, there is a broad groove, similar to that along the proximal parts of the pleural segments of the thorax. The marginal part of the pygidium is inclined downward and is slightly concave, the width of this marginal part varying from 3.5 to nearly 4 cm.

The entire length of the specimen is 36.8 cm., the ratio of this length of the entire individual to the width of the pygidium being almost equal to the ratio of three to two; and the ratio of this length to that of the pygidium alone equals that of twenty-seven to ten. From this it is evident that the length of the entire individual falls short of equalling three times the length of the pygidium.

*Locality and position.* The large specimen of *Isotelus* described above occurred at the western end of the excavation for the conduit beneath the Huffman Conservancy dam, six miles northeast of the center of Dayton, at an elevation of 745 feet above sea, and 162 feet below the base of the Brassfield forma-

tion. The trilobite was lying on its back, and it remained attached to the upper half of the indurated clay layer in which it was imbedded. Five feet above the trilobite horizon was found a single specimen of *Columnaria vacua* Foerste. Since in the northwestern quarter of the Waynesville quadrangle the *Hebertella insculpta* layer, forming the base of the Liberty member of the Richmond formation, lies about 165 feet beneath the base of the Brassfield formation, the horizon at which the large *Isotelus* at the Huffman Conservancy dam was found must be either in the base of the Liberty member or near the top of the Waynesville member of the Richmond formation. The writer is indebted to Arthur E. Morgan, chief engineer of the Miami Conservancy District, for the privilege of studying this specimen.

At the bluff adjoining the southern end of the Huffman Conservancy dam the Brassfield limestone is underlain by the Elkhorn clay shale, 60 feet thick, and this in turn by the Whitewater member of the Richmond, but the line of contact of the Whitewater with the Elkhorn could not be determined on account of the muddy clay adhering to the rock as the result of continuous quarrying operations.

A second large specimen of *Isotelus*, apparently belonging to the same species as the Huffman Conservancy dam specimen was found by Dr. George M. Austin in the *Isotelus* clay layer in the upper or Blanchester division of the Waynesville member of the Richmond formation, at a locality about  $2\frac{1}{2}$  miles northeast of Oregonia, in Warren County, Ohio. This locality is on Roaring Run, about three-quarters of a mile northwest of the Flat Fork school. The length of this specimen was 23.5 cm. The original was an impression in clay, the trilobite lying on its back, and of this impression Dr. Austin secured the plaster of Paris cast, here illustrated on plate XV. In all essentials this smaller specimen is similar to the larger specimen, described above. The ratio of the length of the head to its width is as five to ten. The ratio of the length of the pygidium to its width is 58 per cent. The basal part of the genal spine on the right side of the specimen is preserved, but its tip is gone, so that there is no means of determining its exact length. It probably

reached beyond the posterior margin of the third thoracic segment, possibly as far as the posterior margin of the fourth segment. In this specimen it is not possible to determine how close the anterior parts of the facial sutures are to the anterior margin of the cephalon, since they are not clearly differentiated here. The state of preservation of the thoracic segments and of the pygidium is excellent, and this is the chief reason for presenting here a figure of this smaller specimen. In the collections at Wilmington College, in Ohio, a cephalon occurs which has a length, along its median parts, of 8.5 cm., and a width of 20 cm. This specimen evidently came from the base of the Liberty formation, since the slab contains also columns of *Glyptocrinus richardsoni* Wetherby, which is characteristic of that horizon.

*Remarks.* Both the Huffman Conservancy dam specimen and the Roaring Run specimen are characterized by cephalons and pygidia which are remarkably short compared with their width. This is true also of the Wilmington College specimen.

Only two species of *Isotelus* have been described from the Richmond formation: *Isotelus maximus* Locke from the Liberty member of the Richmond in Ohio, and *Isotelus iowensis* (Owen) from the Maquoketa member in Iowa.

*Isotelus iowensis* is a much smaller species, 10 to 12 cm. long, with much more elongate cephalons and pygidia, compared with their width.

*Isotelus maximus* is founded on two specimens found in the Liberty member of the Richmond formation a short distance above the mouth of Treber's Run, three-quarters of a mile southwest of Duncanville, and 8 miles southwest of Peebles, Ohio. Here the two types were found by Dr. John Locke in a strongly rippled layer of limestone, the ripples varying from 2 to 3 feet in distance from each other, and the troughs varying from 2 to 3 inches in depth. Similar rippled layers of limestone occur at higher elevations up the run. Both of the type specimens were figured by Dr. Locke (Geol. Surv. of Ohio, 1838, pp. 247-249, figs. 8, 9; see also fig. 1 and 2 on plate XVII of this publication), and they are mentioned again in his description of *Isotelus megistos* Locke (Amer. Jour. Sci., 42, 1842, p. 366, pl. 3, fig.).

The specimen described first by Locke consisted of a fragment of the reflexed margin or doublure of the posterior part of the pygidium; this fragment was 5 inches long and  $1\frac{3}{8}$  inches wide, and it was marked by "veins," but its curvature was so small that it suggested "the end of an ellipse 22 inches long and 12 inches broad." The posterior termination of the axial lobe could be recognized. All of these features are represented in figure 8, accompanying Locke's original description of this species (see also fig. 1 on plate XVII of this publication), but other features are added so as to indicate the relative position of the fragment in the pygidium. Essentially, nothing is known about this type except that its posterior margin was of small curvature. So little of the pygidium is preserved that it is impossible to determine the ratio of the length of the latter to its width. As a type it is worthless.

The specimen described second by Dr. Locke (fig. 9 accompanying his original description; see also figure 2 on plate XVII herewith), consisted of an entire pygidium about  $3\frac{1}{2}$  inches in length, but this pygidium was enlarged by Dr. Locke to twice its natural size, and a thorax and cephalon, based on *Isotelus megalops* Green (Mon. Tril. N. Amer., 1832, p. 70, cast No. 25), was added, producing a drawing 21 inches in length. Only the pygidium of this drawing belongs to *Isotelus maximus*, and this pygidium is distinctly more elongate and more triangular than the pygidia of the Huffman Conservancy dam and Roaring Run specimens described above, the ratio of length to width of Locke's specimen being about 65 per cent.

Although the more perfect pygidium, found by Dr. Locke, was described and figured by him second, it is the only one of the two specimens sufficiently complete to serve as a basis for the identification of other specimens, the first specimen suggesting merely large size but no other specific characters. On this account figure 9 of Locke (fig. 2 on plate XVII of this publication) is chosen as representing the *type* of *Isotelus maximus*; figure 8 *may* belong to the same species as the Huffman Conservancy dam and Roaring Run specimens, described here, but there is no means of determining this with certainty.

Apparently there are two species of *Isotelus* present in the Liberty and Waynesville members of the Richmond of Ohio and adjacent states. One of these has more elongate cephalons and pygidia, and is represented by the pygidium used by Dr. Locke for his figure 9. For this species the name *Isotelus maximus* is retained. The second species, represented by the Huffman Conservancy dam and Roaring Run specimens, has relatively shorter cephalons and pygidia and is regarded as a distinct species for which the name *Isotelus brachycephalus* is proposed.

A large pygidium of *Isotelus* resembling in outline that of *Isotelus maximus* (fig. 9 of Locke), was found in the Stony Hollow, northwest of Clarksville, Ohio, by Prof. S. R. Williams of Miami University. Imbedded in the same slab is *Hebertella insculpta*, and it was found at the extreme top of the Waynesville member of the Richmond group. This pygidium is  $5\frac{1}{2}$  inches long and 7 inches wide, thus indicating that *Isotelus maximus* actually attains as large a size as *Isotelus brachycephalus*, and is not confined to the smaller size used by Locke for his figure 9.

It is customary to refer *Isotelus megistos* Locke (Amer. Jour. Sci., 42, 1842, p. 366, pl. 3; see also plate XVI of this publication) to *Isotelus maximus* Locke. This is natural since Locke himself included the two type specimens of *Isotelus maximus* in his description of *Isotelus megistos*. However, the original description of *Isotelus megistos* begins with a description of a specimen found by Wm. Burnett on the hills at Cincinnati, and this is the specimen figured on the plate accompanying Locke's paper. The horizon at Cincinnati apparently was not in the Richmond but in the upper half of the Maysville formation, possibly in the Corryville. Compared with *Isotelus brachycephalus* both the cephalon and the pygidia of *Isotelus megistos* are more elongate. The eyes are located nearer the posterior margin of the cephalon, and the anterior parts of the facial sutures are much more distant from the anterior margin of the cephalon. The space between the facial sutures, anterior to the eyes, is much more elongate. From this it seems evident that the specimen described by Locke from the Cincinnati hills belongs to a distinct species, for which the name *Isotelus megistos* might be retained.

Considering how abundant the fragments of large specimens of *Isotelus* are at various horizons in the Richmond formation it seems strange that no attempt has been made to illustrate them fully. Our knowledge of *Isotelus maximus* is confined to the few notes and the meager illustrations presented by Locke in his original publication. The numerous citations of *Isotelus maximus* from other authors concern chiefly closely similar, but probably not identical, Trenton forms. The Cincinnati species described by Locke under *Isotelus megistos* also needs further elucidation. It is hoped that the present publication of illustrations of *Isotelus brachycephalus*, and the accompanying observations on *Isotelus maximus* and *Isotelus megistos* will stimulate an interest in the large specimens of *Isotelus* occurring in Ordovician strata.

Accompanying his original description of *Isotelus maximus*, Locke published a figure of this species as though of an individual 21 inches in length. His figure was based upon a pygidium of only half the size of that included in the figure, enlarged so as to correspond in size to a second pygidium of which he had only a fragment of the doublure. In a similar manner Clarke published a figure of *Isotelus maximus*, from the Prosser limestone at Mentorville, Minnesota (Geol. Minnesota, 3, pt. 2, 1894, p. 706, plate) as though of an individual 17 inches in length. His figure was based on a fragment of a large glabella. Both figures are based on estimates; both undoubtedly represented large specimens of *Isotelus*; but actual figures and measurements of large complete specimens are preferable, and an accumulation of such figures and measurements is necessary before the large forms of *Isotelus* can be discriminated successfully into species.

Both of the large specimens of *Isotelus brachycephalus*, here figured and described, were found lying on their back imbedded in the middle of an indurated clay layer. In fact, all of the large specimens of *Isotelus* found by Dr. George M. Austin in place in the Richmond strata of Clinton and neighboring counties in southwestern Ohio, between ten and fifteen in number, were found imbedded in clay and lying on their back. Evidently the specimens were covered by clay before decay dismembered the

pleural segments of the thorax and permitted the free cheeks to separate from the cranidium. Very few specimens that remained in their natural position escaped dismemberment during decay. Dr. Welch, now dead, but formerly also a resident of Wilmington, Ohio, found one of the few specimens ever seen imbedded in a natural position in the rocks, but the parts of his specimen were badly disarranged. These facts suggest a rapid deposition of the clay layers in which the large specimens of *Isotelus* were found.

In Cincinnati areas thin layers of limestone, several inches thick, frequently are interbedded with somewhat thicker layers of clay, often a foot or more in thickness. The limestone layers often consist of more or less comminuted fragments of bryozoans, shells, and other organic remains, and are remarkably free of clay except in very moderate quantities. Apparently the waters that stirred up the organic fragments and removed the clays from the future limestone layers kept these clays more or less in suspension and later permitted their deposition when the violence of the motion of these waters had considerably diminished. In this manner considerable quantities of clay may have been deposited in relatively brief periods of time.

Little is known of sex differences among the trilobites. The presence of both broad and narrow forms of *Isotelus* in the Richmond strata of Ohio and Indiana suggests the possibility that the more elongate forms (*Isotelus maximus*) may be the males, and the broader forms (*Isotelus brachycephalus*) the females of the same species. Our present knowledge does not permit us to determine with any confidence whether the differences noted are connected with sexual differences or not.

### ACROLICHAS

Ohio Journal of Science, XIX, 1919, p. 402.

For the American species at present referred to the European genus *Amphilichas*, the generic term *Acrolichas* is proposed, on account of differences in the structure of the pygidia belonging to the American species. These pygidia have three pairs of ribs,

all with free tips, but only the first two pairs of ribs bear median grooves; moreover, the axial lobe narrows posteriorly to an acute point which reaches the notch between the free tips of the posterior pair of ribs. *Lichas cucullus* Meek and Worthen (Plate XVII, Figs. 4 A,B) is chosen as the genotype. In the Waynesville member of the Richmond formation, in Ohio, *Acrolichas* is represented by *Lichas harrisi* Miller, and a species with coarser pustules is present in the upper part of the Liberty member and the lower part of the Whitewater member of the Richmond.

***Acrolichas* (?) *shideleri* sp. nov.**

*Plate XVII, Figs. 3 A, B*

Two fragments, both interpreted as right free cheeks of some *Lichad.* The general outline is falcate, but along the anterior part of the outer margin of both fragments the curvature is concave. Along its entire length, this outer margin is coarsely striated, the width of the striated border varying from 2 mm. near the posterior end of the free cheek to about 5 mm. along its concave curvature. Posteriorly, these striae are directed diagonally outward and backward. Along the concavely curved part, the striae bend up and down in an evenly concave manner. The remainder of the free cheek, in each specimen, is coarsely papillated, the apex of many of the papillae drooping diagonally downward in a sort of "tear-drop" manner. The inner margin of the tip of the free cheeks shows coarse striae, similar to those along the outer border, but diverging only slightly from this inner margin in direction; these striae can be seen only along the posterior part of the inner margin, within 4 mm. from the tip of the free cheek.

In one of these two fragments, the lower surface of the free cheek was freed from the matrix. This surface is coarsely striated with anastomosing lines, and at its proximal end it shows the inner limit of the test on the lower side of the free cheek. In removing the matrix, the anterior end of the free cheek, with its concave outer margin, was broken off.

*Locality and position.* At McDill Mill, about 6 miles north of Oxford, Ohio, on the main branch of Four Mile creek, half a mile northwest of the point where it is joined by East Fork. In the lower part of the Whitewater member of the Richmond formation, just above the *Gyroceras baeri* (Meek and Worthen) bed. Found by Prof. W. H. Shideler, in whose honor the species is named.

*Remarks.* The reference of these two free cheeks to *Acrolichas* is based chiefly upon their association in the same strata with cranidia undoubtedly belonging to *Acrolichas*, and the fact that these cranidia also bear coarse pustules. The pustules on these cranidia are of two sizes; the conspicuous ones are large and flat, and between these are others which are much smaller. A cranidium found in the basal part of the Saluda, on Hanna creek, one mile east of Liberty, Indiana, by Prof. W. H. Shideler, apparently belongs to the same species as the cranidia associated with *Acrolichas* (?) *shideleri*.

A hypostoma of some species of *Acrolichas*, (plate XVIII, fig. 6) possibly *Acrolichas harrisi* (Miller) was found by Prof. Shideler just above the *Rhynchotrema dentatum* layer in the upper or Blanchester division of the Waynesville member of the Richmond, on Bull Run, less than a mile south of the railroad station at Oxford, Ohio. The anterior, broadly T-shaped half of the hypostoma is covered with numerous small pits. The lateral parts of the hypostoma are striated longitudinally with flexuous and more or less anastomosing lines. Along the posterior median parts, the pits are very minute and distant.

### ***Calymene abbreviata* Foerste**

#### *Plate XVIII, figs. 5 A, B*

*Calymene abbreviata* Foerste, Bull. Sci. Lab. Denison Univ., 16, 1910, p. 83, pl. 3, fig. 17. Jour. Cincinnati Soc. Nat. Hist., 21, 1914, p. 148, pl. I, figs. 14 A, B.

The type of *Calymene abbreviata* was found in the Cynthiana formation, one mile south of Rogers Gap, Kentucky. It is characterized by the straightened, truncated anterior margin of the glabella. The anterior two-fifths of the glabella tends to be

quadrangular, but posteriorly the dorsal furrows diverge widely. Along the anterior margin of the cranidium, the border equals almost a third of the length of the glabella. Cranidia having the same structure occur in the Rogers Gap member of the Cynthiana formation, from Rogers Gap northward as far as Sadieville, Kentucky.

A similar cranidium (plate XVIII, fig. 5 A, B) was found also in the quarry east of Carnestown, on the Kentucky side of the Ohio river. Here it occurred, associated with a single specimen of *Orthorhynchula linneyi*, about 10 feet above the railroad, and 56 feet below the base of the Fulton member, the latter containing *Triarthrus becki*. Forty-two feet below the level of the railroad occur numerous specimens of *Dalmanella bassleri*, *Hallopora multitabulata*, and occasional specimens of *Strophomena vicina*, indicating the presence of typical Trenton strata, such as occur in central Kentucky. Associated with the cranidium mentioned above, occurred a single pygidium, with five pairs of ribs, all of which, excepting those belonging to the last pair, have the distal halves bifurcated by median grooves, as in typical *Calymene senaria*.

**Calymene** sp. (Lorraine form)

*Plate XVIII, fig. 1.*

At the Don Valley brick yards in the northeastern part of Toronto, in Canada, strata occur which are referred to the lower part of the Lorraine formation chiefly on account of the presence of *Trinucleus concentricus*, *Leptaena invenusta*, and *Catazyga headi*, all three associated in the same slabs. Among other species occurring in these slabs are the following: *Climacograptus* (*Mesograptus*) *putillus*, *Iocrinus subcrassus*, *Plectambonites sericeus*, *Dalmanella* sp., *Zygospira modesta*, *Pholidops subtruncata*, *Pterinea demissa*, *Byssonychia radiata*, *Lyrodesma poststriatum*, *Modiolopsis* cf. *concentrica*, *Modiolopsis modiolaris*, *Cyrtolites ornatus*, *Lophospira bowdeni*, *Lophospira tropidophora*, *Sinuities cancellatus*, and a species of *Arthraria* 3 inches long.

With these fossils occurs a species of *Calymene* (Plate XVIII, fig. 1) which resembles *Calymene abbreviata* in the shortness of

its glabella and in the divergence of the dorsal furrows posteriorly, but differs in having a more rounded anterior margin on the glabella, in this respect agreeing with *Calymene meeki*, a species from the Maysville formation of Ohio, Indiana, and Kentucky. In *Calymene meeki* the ribs of the pygidium show only a trace of an impressed groove along their median line. The pygidium of the Don Valley specimens is unknown.

***Calymene retrorsa minuens* var. nov.**

*Plate XVIII, fig. 4*

Compared with *Calymene meeki* Foerste (Bull. Sci. Lab. Denison Univ., 16, 1910, p. 84, pl. 3, fig. 18; also fig. 3 on plate XVIII accompanying this paper), *Calymene retrorsa* Foerste (Bull. Sci. Lab. Denison Univ., 16, 1910, p. 85, pl. 3, fig. 19; also fig. 2 on plate XVIII herewith) is characterized by rounded genal angles; a narrower, less triangular cephalon; and a shorter, less nasute anterior border, in front of the glabella. *Calymene meeki* is characteristic of the Maysville formation; and *Calymene retrorsa* is characteristic of the Waynesville member of the Richmond formation.

In the Whitewater member of the Richmond, both in Ohio and Indiana, a small form of *Calymene* occurs which has all of the characteristics of *Calymene retrorsa* but is constantly of smaller size. For this form the varietal name *minuens* is proposed. The specimen here figured (plate XVIII, fig. 4) was obtained at Richmond, Indiana, by John Misener.

In Ohio, *Calymene retrorsa minuens* is found in Clinton county, on a little branch entering Cowan creek, about a mile southeast of the entrance of the latter into Todd's Fork. Here the Liberty member of the Richmond formation is 43 feet thick. In its upper part, through a vertical range of 5 feet, *Pachydictya fenestelliformis* is fairly common, and a large form of *Strep-telasma rusticum* is abundant. The even-bedded character of the Liberty member is continued into the lower part of the Whitewater member for a distance of 11 feet. Above this level the Whitewater strata become argillaceous and more or less nodular, and specimens of *Calymene retrorsa minuens* begins to make their appearance.

**Calymene** sp. (West Union form)*Plate XVIII, figs. 8 A, B*

The type of *Calymene vogdesi* Foerste (Bull. Sci. Lab. Denison Univ., 2, 1887, p. 95, pl. 8, figs. 12, 16) is a large cranidium with a broad, massive border, separated from the anterior part of the glabella by a broad groove. The glabella is long, the dorsal furrows are not *strongly* convergent, and the anterior margin of the glabella has a broadly rounded outline. The accompanying pygidia have five pairs of ribs. All ribs, except those belonging to the last pair, are grooved for a short distance from the dorsal furrow, and for a longer distance from the distal end of the rib. Along the intermediate part of the ribs, the furrow is very faint or entirely obsolete. This species is characteristic of the Brassfield formation.

In the *Holophragma* zone at the top of the West Union formation at Hillsboro, Ohio, a much smaller species of *Calymene* occurs, (Ohio Jour. Sci., XIX, 1919, p. 402, pl. 18, fig. 6) about three-fifths as large as typical *Calymene vogdesi*. It has about the same form of cranidium, but the anterior half of the glabella is more quadrangular and is truncately rounded anteriorly; the anterior margin of the cranidium is relatively broad, but there is no broad groove separating this border from the anterior margin of the glabella, as in *Calymene vogdesi*.

In the *Trimerus* (formerly referred to *Homalonotus*) *delphinocephalus* zone, about 10 feet above the base of the West Union formation, at the quarry in the southeastern corner of West Union, Ohio, cranidia (figs. 8 A, B, on plate XVIII of this Bulletin) were found which closely resemble those from the *Holophragma* zone mentioned above. They differ chiefly in having a narrower anterior border, which bends more strongly upward, so that, from above, this border appears more narrow than its actual width. The accompanying pygidia show five pairs of ribs, the grooving of which can not be determined from the specimens at hand.

***Calymene niagarensis* Hall***Plate XVIII, figs. 12 A, B*

Specimens from the Rochester shale of New York, furnished by the New York State Museum, through Dr. Ruedemann, have glabellae with a somewhat swollen frontal lobe, elevated rather abruptly above the frontal margin. The articulating margin along the anterior of the pygidium curves outward from the axial lobe and then backward to the posterior margin. When the axial lobe is placed in a horizontal position the posterior margin of pygidium appears rounded or slightly angular. The axial rings are transverse, about 7 in number, leaving only a very short posterior undifferentiated end.

***Calymene breviceps* Raymond***Plate XVIII, fig. 7*

*Calymene breviceps* Raymond, Bull. Mus. Comp. Zool. Harvard Univ., 60, 1916, p. 27, pl. 3, fig. 11.

Specimens of the *Calymene* which is common in the Waldron shale at Newson, Tennessee, compared with typical *Calymene niagarensis*, have a somewhat flatter frontal lobe on the glabella, and this frontal lobe rises less above the anterior margin of the cranidium. The axial lobe of the pygidium has more convergent sides; the axial rings are curved, especially the anterior ring. When the axial lobe is placed in a horizontal position, the posterior margin of the pygidium is less curved and frequently has an almost transverse outline.

***Calymene cedarvillensis* sp. nov.***Plate XVIII, figs. 11 A, B, C*

In the Cedarville dolomite, in the quarry at Cedarville, Ohio, a large species of *Calymene* is found, equalling *Calymene vogdesi* in size. The only complete specimen found, more or less distorted by pressure along its right side and along its anterior

margin, originally must have been nearly 95 mm. in length. The glabella has about the same structure as the glabella of the other Silurian species here described; it is relatively long, the anterior part tends to be quadrangular, and the dorsal furrows do not diverge strongly posteriorly. The chief difference from *Calymene vogdesi* consists in the narrower anterior border which is not separated from the anterior part of the glabella by a groove distinct from the general curvature of the border. Compared with *Calymene celebra* Raymond (Bull. Mus. Comp. Zool. Harvard Univ., 60, 1916, p. 28, pl. 3, figs. 9, 10) its anterior border is considerably wider. Of the pygidium not much is known, but the shallow groove along the top of the ribs appears nearer the posterior margin of these ribs, at least along their distal half.

All of the Trenton and Cincinnati species of *Calymene* in American strata known to the present writer have the abbreviated form of glabella, with the strongly divergent dorsal furrows. All of the Medinan and Niagaran species have the more elongate form of glabella, with the more moderately divergent dorsal furrows. The Trenton species include *Calymene senaria* Conrad, and *Calymene abbreviata* Foerste. The Cincinnati species include *Calymene granulosa* Foerste, *C. meeki* Foerste, *C. retrorsa* and variety *minuens* Foerste, *C. fayettensis* Slocum, and *C. gracilis* Slocum. *Calymene callicephala* Green may have been founded on a poorly preserved erratic specimen of *Calymene senaria*. The Medinan species include *Calymene vogdesi* Foerste, and the Niagaran species include *Calymene niagarensis* Hall, *C. breviceps* Raymond, *C. celebra* Raymond, and *C. cedarvillensis* Foerste.

### **Encrinurus ornatus** Hall and Whitfield

#### *Plate XVIII, figs. 9 A, B*

*Encrinurus ornatus* Hall and Whitfield, Pal. Ohio, 2, 1875, p. 154, pl. 6, fig. 16.

The type of *Encrinurus ornatus* was found in the Cedarville dolomite at Cedarville, Ohio. It is doubtful whether this species occurs at any other horizon than in the Cedarville dolomite, although closely similar forms occur at other horizons. This species is found in the Cedarville dolomite not only at Cedar-

ville but also at the Moody quarry, in the southeastern part of Wilmington, Ohio, from which specimens occur in the collection of Dr. George M. Austin. The pygidium, in the best preserved interior cast found in this collection, figured herewith, has 7 pairs of ribs, of which the last pair is very short and is indicated chiefly by the nodular elevation of part of this rib. A cast of the exterior of another specimen suggests the possibility of an eighth pair of ribs, but this is doubtful. The chief characteristic of the species, as far as known, is found in the curvature of the ribs. The axial lobe is almost straight from front to rear. From this lobe all of the anterior ribs diverge strongly, and the backward curvature of their distal halves is more moderate than in any other Silurian species. The posterior termination of the pygidium of this species is unknown.

In *Encrinurus reflexus* Raymond (Bull. Mus. Comp. Zool., 60, 1916, p. 25, pl. 3, figs. 7, 8) from the Niagaran at Wauwatosa, Wisconsin, there are 8 pairs of ribs, and these are deflected more strongly toward the rear.

### ***Encrinurus hillsboroensis* sp. nov.**

*Encrinurus* cf. *ornatus*, Ohio Jour. Sci., 1919, p. 391, pl. 18, figs. 2 A-C.

In the *Holophragma* zone, at the top of the West Union formation, at Hillsboro, Ohio, fragments of a species of *Encrinurus* occur which differ from either *Encrinurus ornatus*, or *Encrinurus reflexus* in the strong posterior reflexion of the distal parts of the ribs on the pygidium. There are 8 pairs of ribs and the pygidium terminates posteriorly in an acute spinose end. It is probable that a similar termination would be found also on the pygidia of other species if these parts were preserved.

In *Encrinurus thresheri* Foerste (Bull. Sci. Lab. Denison Univ., 2, 1887, p. 101, pl. 8, fig. 26; also pl. XVIII, fig. 10 of present issue) the ribs curve strongly backward as in *Encrinurus hillsboroensis*, but there are only 6 pairs of distinctly defined ribs, with a doubtful seventh pair parallel to the posterior end of the axial lobe. The type apparently is a cast of the lower surface of the pygidium, which accounts for the apparent narrowness of the ribs.

## ADDITIONAL NOTES ON BRASSFIELD ECHINODERMATA

Since the publication of the article on the echinodermata of the Brassfield Formation, in the earlier part of this volume, Mr. Frank Springer, the eminent American authority on Crinoidea, has kindly offered the following notes on several of the specimens there figured.

The broad, flat calyx, represented by figures 2 A, B, C, and D on plate VI, belongs to the *Rhodocrinidae*, and may be similar to the form described by Weller, from the Racine of the Chicago area, as *Archaeocrinus depressus*. Hitherto we have supposed this genus to be purely Trenton and Chazyan, but the Racine and Brassfield forms appear to be close to it.

The specimen retaining both calyx and arms, obtained at the Centerville quarry, and forming figure 3 on plate III, is of the type *Patelliocrinus* Angelin, one of the rare Gotland forms, but the preservation of the Centerville specimen is tantalizing, and one does not feel sure of the structure.

The fragments of calyx and arms forming figures 4 A, B, on plate III, also found at the Centerville quarry, apparently belong to the *Flexibilia*, and very probably is *Pycnosaccus*, as far as can be determined in the absence of an entire calyx.

The problematical specimen described on page 28 as *Stereoaster squamosus* forms the genotype of *Stereoaster*, the latter being a new generic term, a fact not indicated in the text at the time of its original publication.

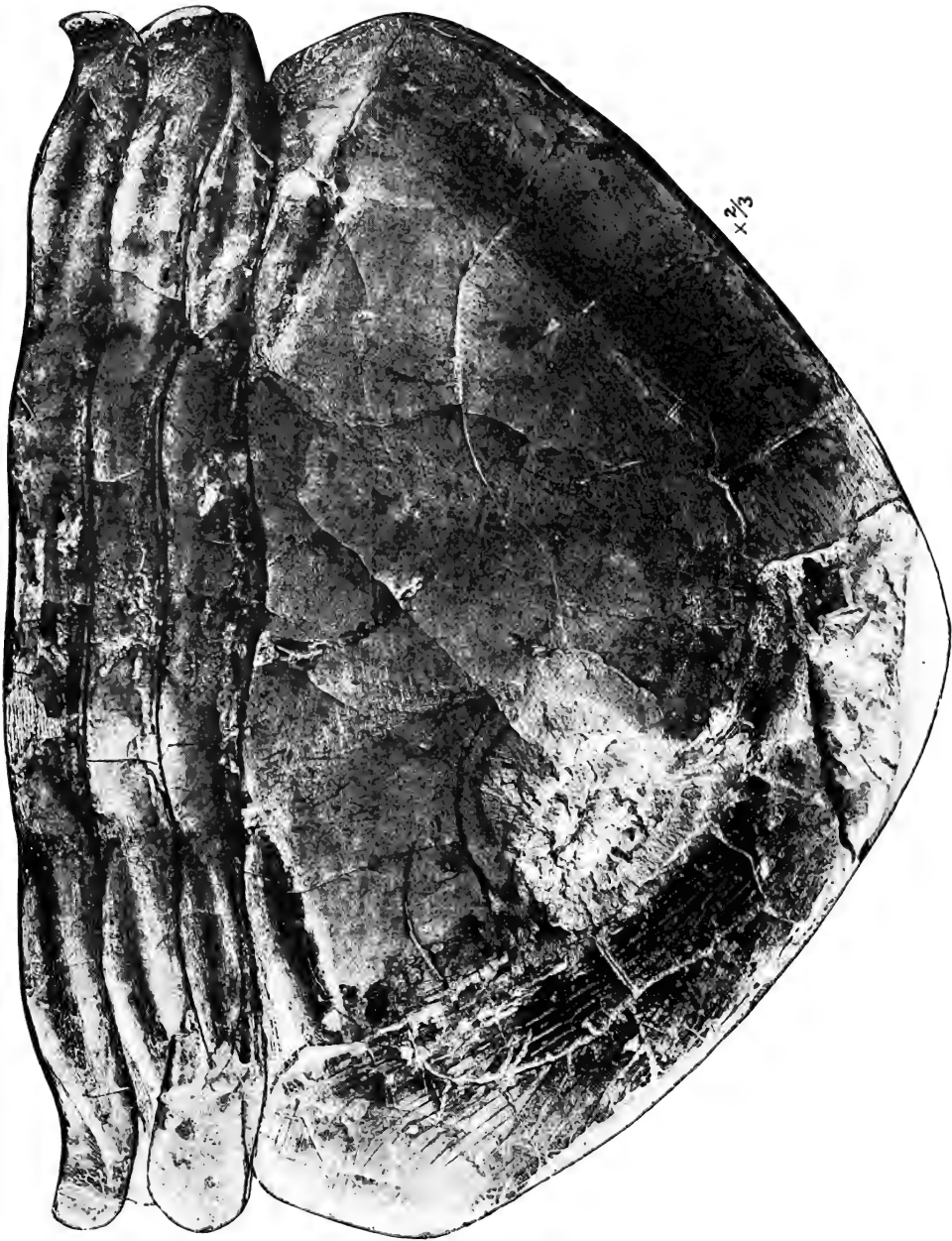
#### PLATES XIV AND XIV A

*Isotelus brachycephalus* sp. nov.; type. An entire individual, figured in two parts, reduced in size. The cephalon and the five anterior segments of the thorax are shown on plate XIV; the pygidium and the three posterior segments of the thorax are shown on plate XIV A. The former presence of a genal spine is seen on the left side of the cephalon. The length of this spine is unknown. Parts of the reflexed lower margins of the free cheeks and of the pygidium are seen on the left side of the specimen. Found in the base of the Liberty or the top of the Waynesville member of the Richmond, at the Huffman Conservancy dam, 6 miles northeast of the center of Dayton, Ohio. Loaned by Arthur E. Morgan, Chief Engineer.





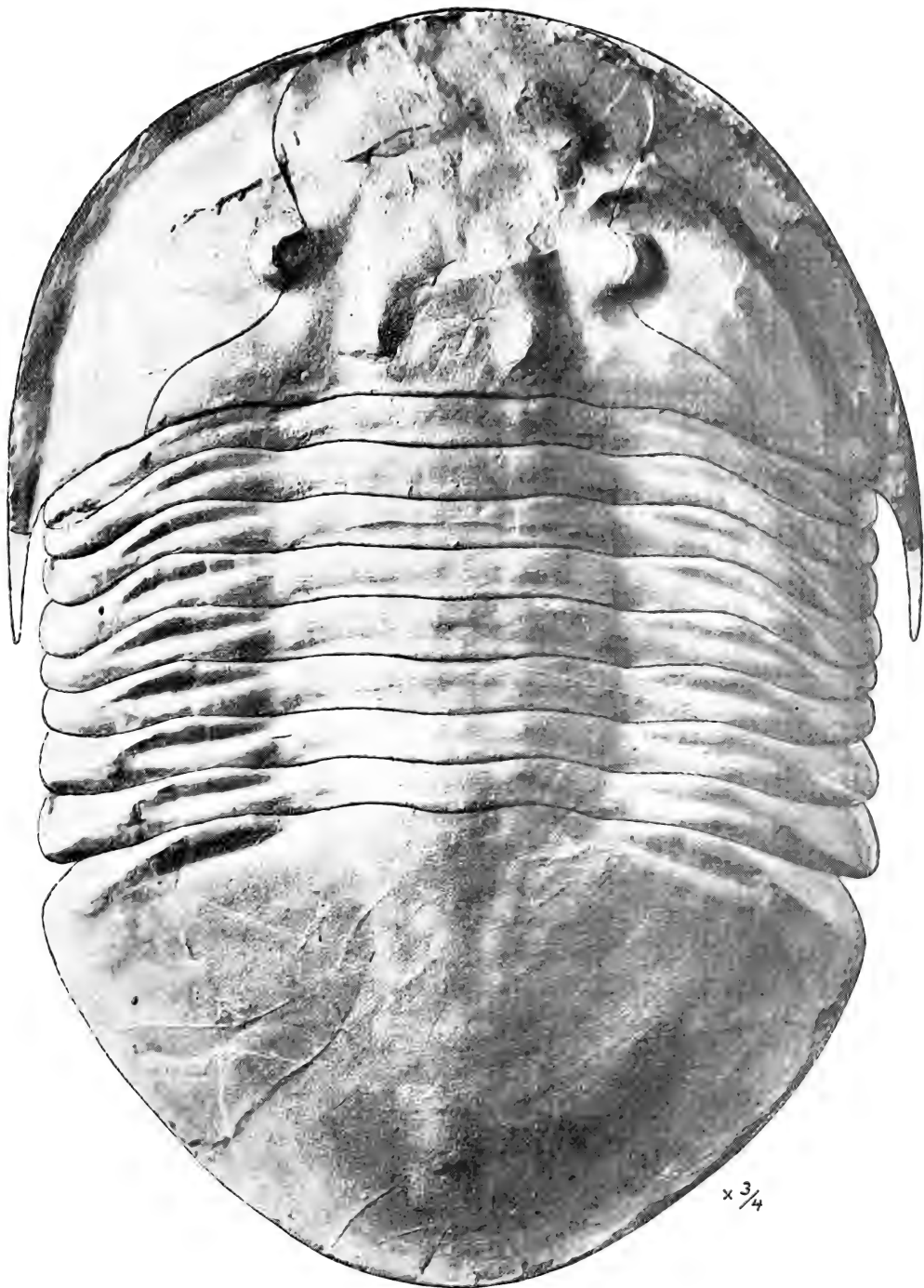
FOERSTE: ORDOVICIAN TRILOBITES



FOERSTE: ORDOVICIAN TRILOBITES

#### PLATE XV

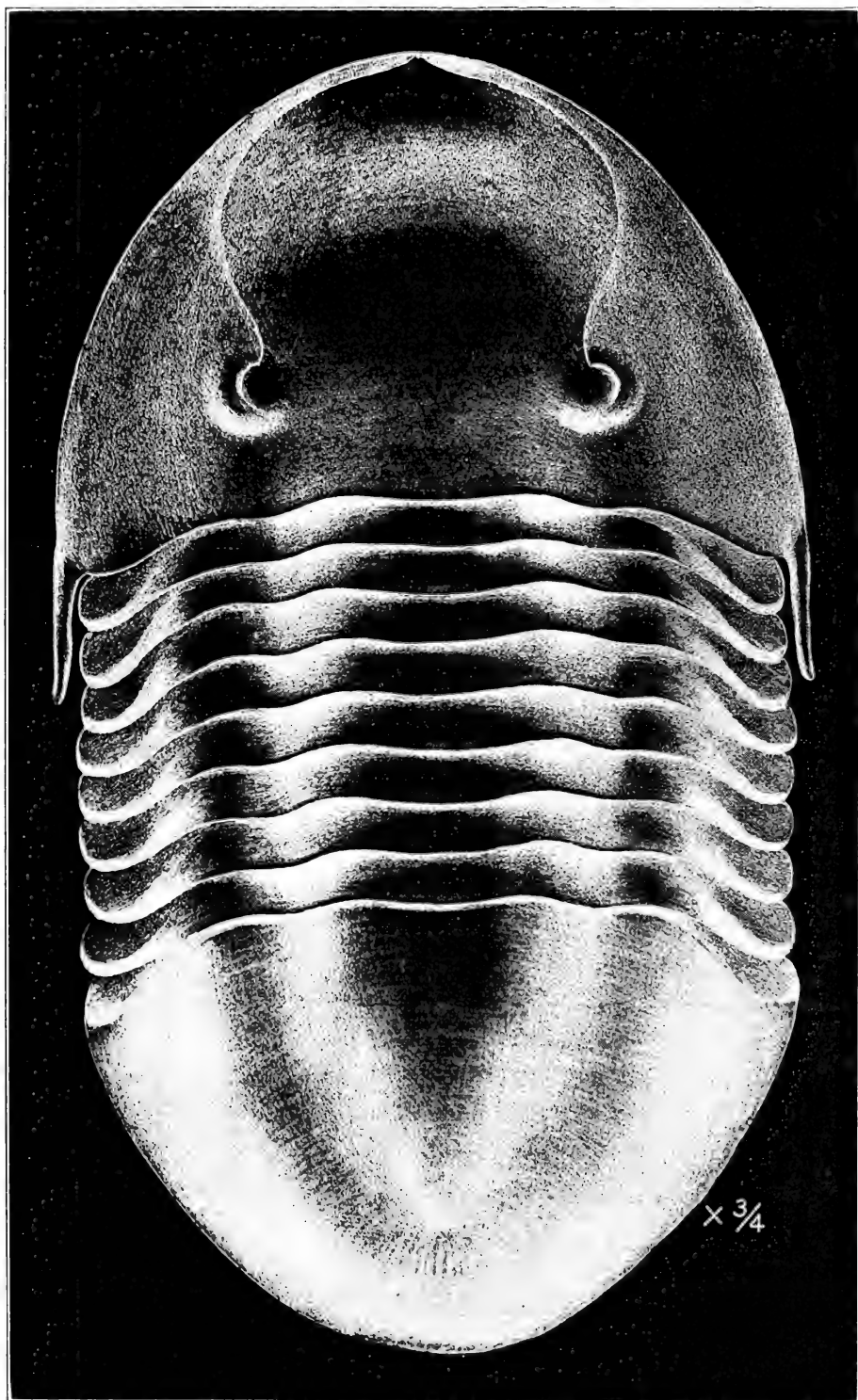
*Isotelus brachycephalus* sp. nov. A cast showing the upper surface of an entire individual, in a remarkably good state of preservation; figure reduced in size. Found in the upper or Blanchester division of the Waynesville member of the Richmond, about  $2\frac{1}{2}$  miles northeast of Oregonia, Ohio, on Roaring Run, by Dr. George M. Austin.



FOERSTE: ORDOVICIAN TRILOBITES

## PLATE XVI

*Isotelus megistos* Locke; type specimen, described and figured in the American Journal of Science, vol. 42, in 1842; p. 366; pl. 3. Found by Wm. Burnett on the hills at Cincinnati, Ohio, presumably in the upper part of the Maysville formation.



FOERSTE: ORDOVICIAN TRILOBITES

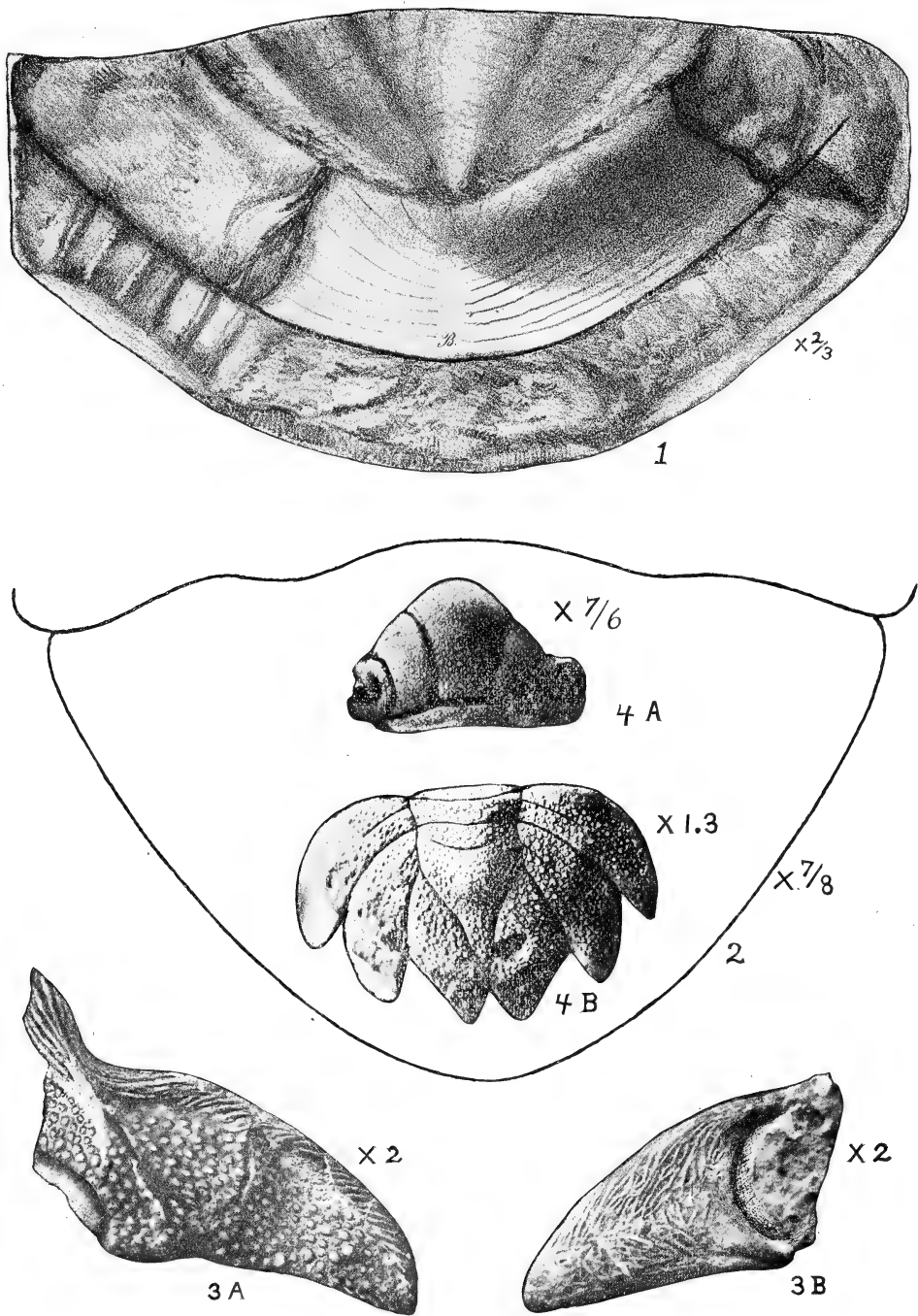
## PLATE XVII

Fig. 1. *Isotelus maximus* Locke; one of the types figured by him in Geol. Surv. Ohio, 1838, pp. 247-249, plates 8 and 9. As the first published figure, this should be the type, but of this entire figure only that part was based on an actual specimen which is included in the marginal part of the pygidium, where the lower, reflexed doublure is shown by the removal of the upper part of the pygidium. This part is not regarded as sufficient to determine the outline of the pygidium. All of the remainder of the drawing was added to "place" the fragment in its proper surroundings in the pygidium. Found in the Liberty member of the Richmond, on Treber Run, 8 miles southwest of Peebles, Ohio.

Fig. 2. *Isotelus maximus* Locke; the second one of the types figured by Locke, as figure 9, found at the same locality and horizon as the preceding specimen. Copied from the enormous figure, 21 inches long, presented by Locke. This figure was based on a single pygidium, much smaller than the figure, the outline being based on the entire pygidium at hand and the size being enlarged so as to conform with the imagined size of the individual of which figure 8 illustrates only a fragment. Probably two species are represented by figures 8 and 9 of Locke. Of these, figure 9 is the only one including enough of an individual to make possible the identification of the type. In the opinion of the writer, either Locke's name, *maximus*, should be dropped or the name should be attached to the specimen represented by figure 9, which there is some chance of identifying, in the entire absence of Locke's types.

Fig. 3. *Acrolichas* (?) *shideleri* sp. nov. A, upper surface of a fragment regarded as a free cheek. B, under surface of a second, similar free cheek. Found in the Whitewater member of the Richmond, at McDill's Mill, 9 miles north of Oxford, by Prof. W. H. Shideler.

Fig. 4. *Acrolichas cucullus ottawaensis* var. nov. A, cranidium; B, pygidium. From the Trenton at Hull, opposite Ottawa, Canada. Collected by J. E. Narraway. Differing from the type chiefly in the rounded free tips of the ribs on the pygidium.



FOERSTE: ORDOVICIAN TRILOBITES

## PLATE XVIII

Fig. 1. *Calymene* sp. (Lorraine form). Enrolled individual from Lorraine formation at Don Valley brickyards at Toronto, Canada.

Fig. 2. *Calymene retrorsa* Foerste. Lateral view of type; see Bull. Sci. Lab. Denison Univ., 16, 1910, p. 85, pl. 3, fig. 19. From middle or Clarksville division of Waynesville member of Richmond formation, on Silver Creek, east of Dunlapville, Indiana.

Fig. 3. *Calymene meeki* Foerste. Lateral view of type; see Bull. Sci. Lab. Denison Univ., 16, 1910, p. 84, pl. 3, fig. 18. From Fairmount member of Maysville formation, at Cincinnati, Ohio.

Fig. 4. *Calymene retrorsa minuens* Foerste. Enrolled specimen, from White-water member, at Richmond, Indiana, collected by John Misener.

Fig. 5. *Calymene abbreviata* Foerste. *A*, cranidium; *B*, pygidium, with posterior part preserved. From Cynthiana formation at quarry east of Ivor, Kentucky.

Fig. 6. *Acrolichas harrisi* (Miller) (?). Hypostoma; found in Blanchester division of Waynesville member of Richmond formation, on Bull Run, southwest of Oxford, Ohio, by Prof. W. H. Shideler.

Fig. 7. *Calymene breviceps* Raymond; the posterior part of the occipital ring is broken off. Glabella. From Waldron shale at Newsom, Tennessee.

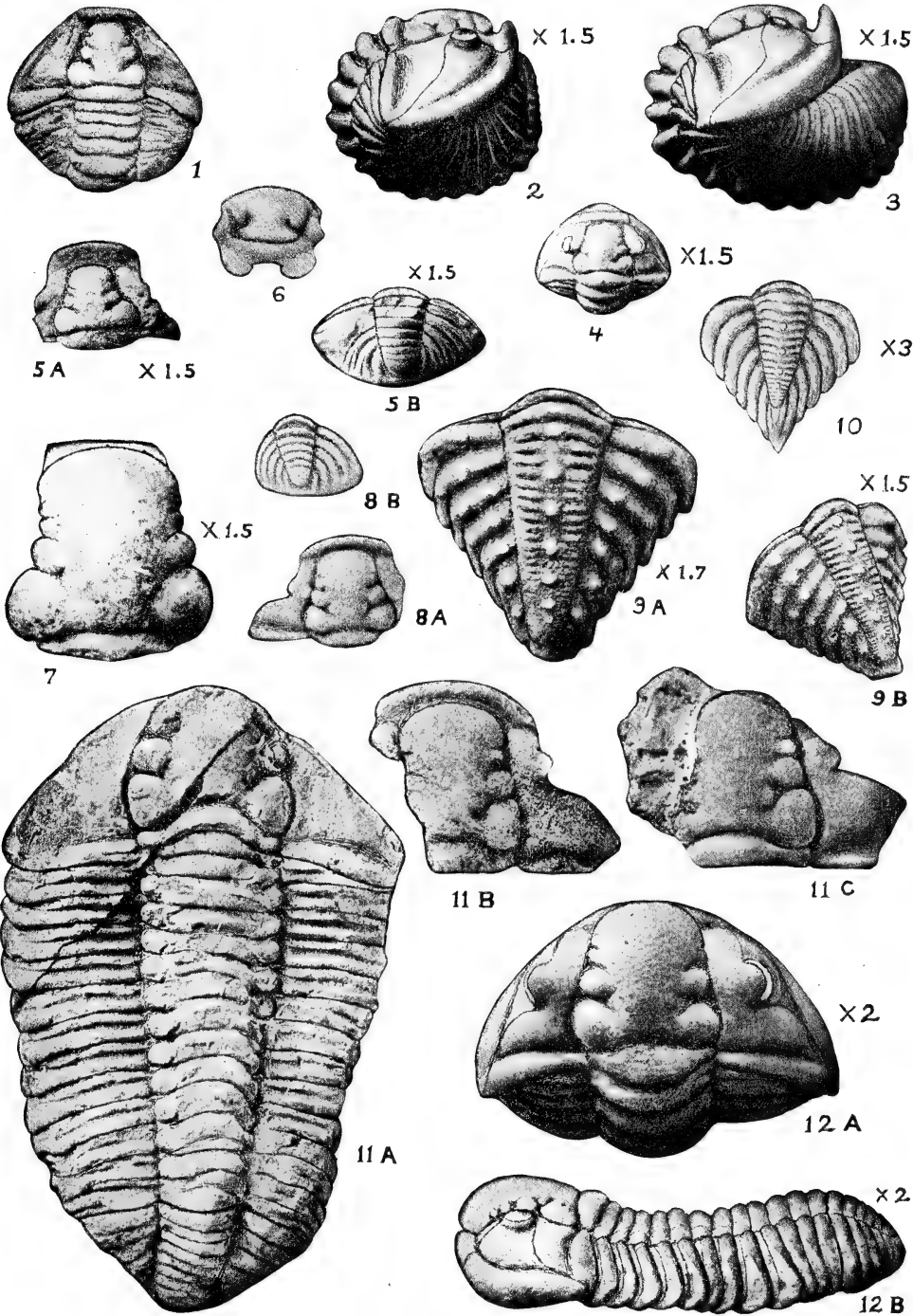
Fig. 8. *Calymene* sp. (West Union form). *A*, cranidium; *B*, pygidium. From the *Trimerus delphinocephalus* zone, ten feet above the base of the Bisher member of the West Union formation.

Fig. 9. *Encrinurus ornatus* Hall and Whitfield. *A*, pygidium, with the posterior tip missing; *B*, lateral view of same. From the Cedarville dolomite at the long abandoned quarry southeast of Wilmington, Ohio, west of the county infirmery.

Fig. 10. *Encrinurus thresheri* Foerste. Pygidium, with the posterior tip not clearly exposed, and with the anterior margin of the axial lobe missing; both restored. Type; see Bull. Sci. Lab. Denison Univ., 2, 1887, p. 101, pl. 8, fig. 26. From the Brassfield formation, at Dayton, Ohio.

Fig. 11. *Calymene cedarvillensis* Foerste. *A*, entire individual with right side and anterior margin distorted by crushing; *B*, part of cranidium; *C*, fragment of another cranidium. From the Cedarville dolomite at Cedarville, Ohio.

Fig. 12. *Calymene niagarensis* Hall. *A*, cephalon of enrolled specimen; *B*, lateral view of extended specimen. From the Rochester shale of New York, loaned from the New York State Museum, at Albany, through the courtesy of Dr. Rudolph Ruedemann.



FOERSTE: ORDOVICIAN AND SILURIAN TRILOBITES



## SOME SUGGESTED EXPERIMENTS FOR THE GRAPHIC RECORDING OF SPEECH VIBRATIONS

ROBERT JAMES KELLOGG

In an attempt to recast the science of phonetics on the basis of connected speech flow,<sup>1</sup> I have found it necessary to critically compare the results obtained by different methods of graphically recording speech vibrations. Out of this comparison a number of suggestions have emerged (1) for further perfecting certain existing types of apparatus, (2) for the application of apparatus already perfected to special linguistic problems, and (3) for the development of new types of apparatus in which the "light-lever" (or shifting ray of light responding to sound vibrations) partly or wholly replaces the physically vibrating parts.

These suggestions are presented herewith in the hope that they may be of interest and help to other investigators, and also that, if a larger number can cooperate in working them out, the practical and mechanical difficulties involved may be the sooner solved and the apparatus based on these principles devised and perfected.

### I. THE PERFECTING OF EXISTING TYPES OF APPARATUS

It cannot be too strongly insisted that the mechanical perfection of diverse types is necessary if the problems of experimental phonetics are to be fully solved. Every type of sound recording apparatus distorts the sound curves in its own special way, suppressing, damping, modifying or adding specific vibrational elements. Even in the perfected apparatus this distortion may either require complicated correction of results (as in the phonodeik), or it may not be fully determinable from the unaided standpoint of the apparatus in question (as in the case

<sup>1</sup> Proc. Mod. Lang. Assoc., 1915, p. xxix, title 46: About face in fonetics.

of the manometric flame). But the results of diverse types of apparatus check and interpret each other. Thus in the case of the two types just mentioned, the phonodeik<sup>2</sup> gives legible sinusoidal records of even the minutest elements and phases of vibration, showing distinctive curves even of voiceless consonants and whisper sound,<sup>3</sup> but its records require varied and complicated corrections of horn and diaphragm effects.<sup>4</sup> The manometric flame as developed by Nichols and Merritt<sup>5</sup> is non-sinusoidal in its record and therefore hard to interpret, but it is apparently freer than any other apparatus from special mufflings and reinforcements. It is equally able to show the highest and minutest vibrational elements and phases.<sup>6</sup> Apparently therefore these two types of apparatus are complementary, each approaching perfection where the other is most defective.

Furthermore, it is impossible to forecast either the kind or value of results obtainable with any type of apparatus until it is perfected and its results thoroughly tested out. Thus, the phonograph and gramophone are merely perfected forms of Scott's crude phonautograph, which, though it has failed thus far to produce the visible graphic record originally sought, produces in these perfected forms practically perfect results in a new and unforeseen direction. Nichols and Merritt's manometric flame apparatus shows that Koenig's manometric figures consisted of partly overlapping images, which effectively concealed all minor phases of vibration, but that with a vibrating flame of high actinic power and high speed of the recording film, these figures are resolved and the minutest phases and shades of vibration clearly recorded. The phonodeik, with its marvellous sensitiveness to the minutest and most rapid vibratory movements, shows an equally marked advance over the cruder instruments of the same type developed by Blake, Argollet and Chavanon, Lebedeff, and Somojloff. Thus the three types

<sup>2</sup> Miller, *Science of Musical Sounds*. New York, 1916.

<sup>3</sup> *Ibid.*, figs. 170, 171, 172, 184; *Phys. Rev.*, xxviii, 151 ff.

<sup>4</sup> *Ibid.*, ch. V.

<sup>5</sup> *Phys. Rev.*, i, 166-176, and vii, 93-101.

<sup>6</sup> See illustrations under the second article cited in note 5.

of apparatus (phonograph, phonodeik and manometric flame) which have been brought nearest to mechanical perfection, have all been developed out of exceedingly defective and seemingly unpromising types. It is therefore precarious to reject any type of apparatus on a-priori grounds, and surely worth while to study the problem of perfecting existing types of apparatus and devising new ones.

*Enlargement of phonographic and gramophonic records.* It is highly probable both on practical and theoretic grounds that the direct phonautograph type cannot be perfected to produce accurate sound curves large enough for direct reading. This appears both from the negative results attending long years of efforts and experiments directed to improving the phonautograph,<sup>7</sup> and from the fact that the degree of magnification, the inertia, length and flexibility of levers, and the amplitude of vibration demanded at the recording point are so great that the physical mechanism cannot conform to the rapid and complexly changing phases of speech vibration, and also necessarily introduces interfering vibrational elements of its own. But in the form of the phonograph and gramophone, the phonautograph has been brought to approximate mechanical perfection for the production of audible records, and the phonograph and gramophone grooves are therefore approximately perfect physical records of speech vibrations on a microscopic scale. Various means of enlargement have been tried in the effort to render the sound grooves legible.

Direct magnification<sup>8</sup> of the sound groove has thus far proved unsatisfactory for the phonograph and impossible for the gramophone. In the phonograph groove the sinusoidal element is perpendicular to the surface and therefore in the line of sight, and hence disappears both in direct microscopic observation by the eye and in microphotographic enlargement. The gramophone groove is indeed sinusoidal in the plane of the record, but the length of the sinusoids is so great in comparison with their

<sup>7</sup> Scripture, *Elements of Experimental Phonetics*. New York, 1902, pp. 17-24.

<sup>8</sup> Cf. Marichelle, *La parole d'après le tracé du phonographe*. Paris, 1897. See also Boeke in Pflueger's *Archiv*, 1891, p. 297.

amplitude that they are wholly illegible on any scale of enlargement. In other words, the difficulty rests for both instruments in the fact that the record is not made for visible but only for audible purposes. The remedy obviously lies in constructing phonograph and gramophone records for the express purpose of microscopic enlargement without regard to their fitness for audible reproduction (though a synchronous audible record could also be made for comparison if desired).

In the case of the phonograph, a micro-legible record could be made by using a wedge-shaped cutting sapphire (that is, one with two straight cutting edges meeting in a point), thus making the depth and width of the groove proportional and the edges true sinusoids of the sound vibrations recorded, and as such capable of direct microscopic enlargement and photographic reproduction and interpretation. Whether it could be made more easily legible and photographable by a surface coloring of the wax, could be determined by trial.

In the case of the gramophone, a micro-legible record could easily be made by sufficiently reducing the speed of the recording disk, thus foreshortening the vibrational curves to legible sinusoids. Such a record ought to be easily magnifiable sufficiently to show the minutest phases of vowel and consonant vibrations.

The unsatisfactory results hitherto attending microscopic enlargement of the sound groove led to various efforts at indirect enlargement, either by physical levers (as by Scripture,<sup>9</sup> Muenzinger<sup>10</sup> and others), or by physical and light-levers combined (as by Hermann,<sup>11</sup> Rosset<sup>12</sup> and others).

Scripture apparently carried the simple lever apparatus to the limit of its possibilities. He himself adjudges it inadequate and believes that "the future of the method lies in the develop-

<sup>9</sup> Elements of Experimental Phonetics, ch. IV, and Study of speech curves, Washington, 1906, ch. II.

<sup>10</sup> Bull. of Univ. of Texas, no. 24, April, 1915.

<sup>11</sup> See Elements of Experimental Phonetics, p. 38 ff, with the references there given.

<sup>12</sup> Recherches expérimentales pour l'inscription de la voix parlée. Paris, 1911.

ment of a compound lever."<sup>13</sup> He believes this inadequacy is due to the low degree of magnification obtainable (125 to 300 times). But a comparison of his results with those of Hermann, Rosset, Marichelle and Miller, shows that the failure of Scripture's apparatus to record consonantal and overtone vibrations is due to its low limit of sensitiveness and not to its low degree of magnification. Thus Marichelle shows the occlusive and explosive phases of voiceless consonants with a magnification of less than thirty diameters.<sup>14</sup> Miller's record of *Lowell Institute* as recorded in his *Science of Musical Sounds*<sup>15</sup> has a magnification only a little greater than that given by Scripture's apparatus, but it plainly shows the vibrations of even the occluded phases of *s* and *t*.

Muenzinger's compound lever apparatus neutralizes the weight of all levers through counterbalancing, and practically eliminates play and friction of bearings and joints by point or V-bearings. His first results do not exceed those obtained with Scripture's simple lever apparatus. Muenzinger's apparatus ought to be further developed and perfected in order to determine its full possibilities. Apparently any further progress in physical lever magnification of the sound groove must follow the lines that he has laid down. The future of the method must lie, not in seeking greater magnification as Scripture supposed, but in seeking greater sensitiveness, perhaps with lower magnification if that is necessary to secure it. The absorption of minute vibrational phases (due in Scripture's apparatus to play of bearings, infinitesimal bending of levers, and friction of the recording stylus) must be eliminated. Muenzinger's V-bearings will probably solve the first difficulty. The bending can perhaps be eliminated by using very light levers with delicate trussing or wire bracing, which are kept at a fixed temperature; the method probably cannot be perfected unless such rigid and delicate levers can be obtained. For the recording surface some

<sup>13</sup> Study of Speech Curves, p. 26.

<sup>14</sup> La parole d'après le tracé du phonographe, figs. 83-86, p. 80.

<sup>15</sup> Figure 184, p. 254.

substance or surfacing approaching absolute smoothness must be sought.

Decidedly better results have been obtained by the combination of physical levers with light-levers. Hermann's work on this line (cited above) is well known. It is worth while, however, to call especial attention to Rosset's apparatus. A tiny concave mirror attached to the reproducing stylus of the phonograph reflects a beam of light to the recording screen, thus giving synchronous graphic and auditory records of the sound waves, the latter record testing and interpreting the former, and enabling him to perfect his apparatus. Fuller details of his method are given in his *Recherches expérimentales*, cited above. For want of adequate funds, his experiments were confined to working out the principle. With a lateral magnification of 250 times, he secured distinctive records not only of vowels, voiced consonants and spirants, but also of explosive *t*, of on and off glides in connected speech, and of the gradually changing form of the so-called simple vowels. His apparatus is probably capable of being brought to an extreme degree of delicacy and perfection, and the principle he uses may be capable of other applications. It would be well if some of our American laboratories could help in this development.

*Sinusoidal manometric flame records.* One other type of recording apparatus probably capable of being more fully perfected is the sinusoidal manometric flame record of J. G. Brown.<sup>16</sup> The direct non-sinusoidal form of the manometric flame has been approximately perfected by Nichols and Merritt, as noted above. Brown succeeded in obtaining a sinusoidal record by turning the exit tube of the manometric capsule on a downward slant, thus obtaining a curved flame with its outer portion curving upward and describing up and down harmonic motions with the variations of vibratory pressure in the manometric capsule. By using a clear actinic flame good photographic records of the flame sinusoids were obtained, as shown in illustrations in the article just cited. By using a smoky flame a sinusoidal record

<sup>16</sup> Phys. Rev., xxxiii, 442-446.

was deposited in soot on a revolving tambour. But the soot record is not wholly satisfactory because different portions of the flame deposit separate superposed records not wholly agreeing in form, as only the lower edge of the flame gives a true sinusoid. So far as published, Brown's apparatus was applied only to a few simple vowel sounds and its power of recording finer and higher speech sounds remains to be tested. But the extreme sensitiveness of the manometric flame as demonstrated by Nichols and Merritt, makes it probable that his apparatus could be developed and used along this line. It would therefore be of the utmost importance if this method could be so developed as to eliminate the superposed soot figures and give a single clear sinusoidal line. Perhaps this could be effected by using a generally clear flame in which a single tiny soot-producing source is introduced, and from which a fine line of soot would continuously pass to the recording tambour. If the method can be thus perfected, it would give a cheap, efficient and manageable way of producing clear and legible records of connected speech. How important this would be will appear plainly if we reflect that even our best equipped and endowed laboratories find serious mechanical and financial difficulties in making extensive records of connected sentences and words. To be legible the sinusoids must not be foreshortened, and when this condition is fulfilled, the record of even a single syllable becomes several feet long, complete words and sentences correspondingly longer, while a discourse may be measured by the mile. The mechanical difficulty and expense of producing photographic records on this scale is prohibitive. Hence the importance of developing a cheap and efficient means of producing extensive permanent records of connected speech. It would seem to be worth while for different laboratories to coöperate in experiments directed to this end.

## II. APPLICATION TO SPECIFIC PROBLEMS

As to the application of perfected types of apparatus to specific linguistic problems, the chief need is undoubtedly a more extensive and intensive study of the phenomena of colloquial speech

—not merely of intoned vowels or selected syllables or formally enunciated phonographic records, but of actual spoken language in the setting of actual life. If, for instance, the phonodeik, either alone or in conjunction with the manometric flame, could be used to make as careful a study of the spoken language of many different persons, as it was used to make of intoned vowels,<sup>17</sup> it would likely solve many important problems. Note further how many types of apparatus have been barely developed and demonstrated, but for lack of funds never applied to the solution of urgent phonetic problems. Cases in point are the manometric apparatus of Nichols and Merritt and of J. G. Brown, Muenzinger's compound lever apparatus and Rosset's synchronous recording and reproducing apparatus, all of which were noted above. When we consider that language is the vehicle of all of human life and institutions and of all of our knowledge and study of the outside world, it may be reasonably contended that no other single phenomenon is a more important object of investigation. The scientific study of its different phases has already yielded writing, printing, telegraphy, the telephone, and the phonograph, besides making important contributions to psychology and physiology, as in the case of the doctrine of cerebral localizations which is a part of the basis of modern surgery. It is devoutly to be hoped that more nearly adequate provision may be made for the scientific study of language in all its phases. To which of our institutions of learning and research will fall the honor of leading in such a movement?

### III. NEW TYPES OF APPARATUS

As to the development of new apparatus of the light-lever type, I would suggest two principles, to which we may provisionally give the names of sonoscope and sonograph, the first involving the elimination of all physical levers but retaining a receiving horn and diaphragm, the second eliminating all resonating and physically vibrating parts, and using a light-lever

<sup>17</sup> Science of Musical Sounds, chs. VII and VIII.

whose initial deflection is obtained by refraction as it passes through free sound-transmitting air. The purpose is to develop, if possible, an apparatus combining great sensitiveness and high magnification with minimum distortion, and constructible at moderate expense in the average laboratory of limited means and equipment.<sup>18</sup>

*The sonoscope.* The principle of the sonoscope is shown in three forms in figures 1, 2 and 3. It consists essentially of a receiver horn *H*, with a thin mirror-diaphragm *D* (probably of silvered glass or mica, or perhaps of polished metal) from which

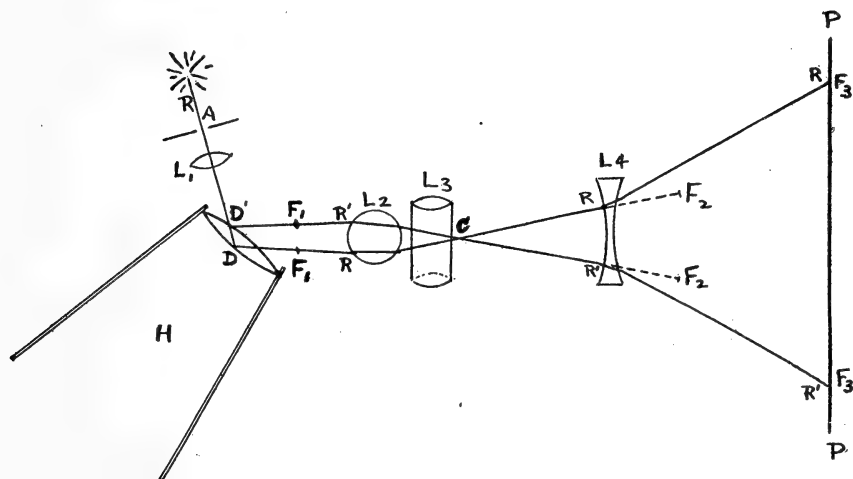


FIG. 1. PRINCIPLE OF THE SONOSCOPE, FORM A (HORIZONTAL SECTION)

a ray of light (or light-lever) *R* is reflected to the demonstration screen or photographic film *P*. The ray is received through the pinhole aperture *A*, focussed by the lens *L*<sub>1</sub>, falls at an oblique angle (say 30 degrees) on the vibrating mirror-diaphragm, whose varying vibratory positions *DD'* shift the ray to varying paths *RR'*. These paths are nearly parallel or slightly divergent with an extreme separation of perhaps 0.005 or 0.010 of an inch, more or less, according to the amplitude of vibration which

<sup>18</sup> If either of these principles proves successful, acknowledgment will be due to Prof. D. C. Miller, as the ideas were partly suggested to me by the phonodeik.

proves feasible for the diaphragm. The divergence of the paths  $RR'$  is increased by refraction or reflection, thus causing the ray or light-lever to describe on the screen  $P$  an enlarged representation of the vibratory movements of the diaphragm  $D$ .

In form A (fig. 1), the paths  $RR'$  are made convergent by a lens of crossed glass or quartz fibers  $L_2L_3$ , whose proper radius of curvature (perhaps from 0.01 to 0.02 of an inch) must be experimentally determined. The paths  $RR'$  diverge again beyond the crossing point  $C$ , and when sufficiently far apart, have their rate of divergence increased by the concave lens  $L_4$  (or by a convex glass-tube mirror, which can be made in the

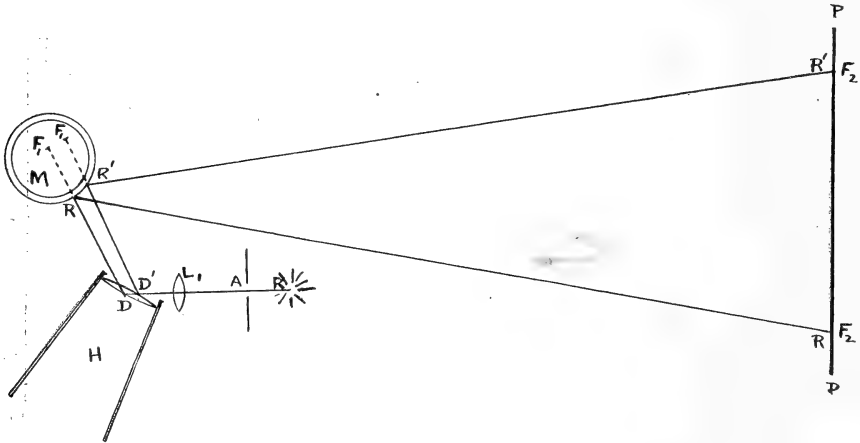


FIG. 2. PRINCIPLE OF THE SONOSCOPE, FORM B (HORIZONTAL SECTION)

laboratory). The exact location of the various lenses must be such as to focus approximately the light-lever  $R$  on the screen  $P$ . The first focus of lens  $L_1$  must fall between the diaphragm  $D$  and the fiber lens  $L_2L_3$ ; the second focus  $F_2$  of the lens  $L_2L_3$  will fall beyond the crossing point  $C$ , because divergence within the ray before reaching the fiber lens  $L_2L_3$  is greater than that between its paths  $RR'$ . The concave lens (or convex mirror)  $L_4$  must be placed between the crossing point  $C$  and the second focus  $F_2$ , thus prolonging the focus to  $F_3$  on the film or screen  $P$ .

In form B (fig. 2), a convex glass-tube mirror  $M$  replaces the lenses  $L_2L_3$  and  $L_4$  of form A. The first focus  $F_1$  must fall be-

yond the mirror  $M$ , which prolongs the focus to  $F_2$  on the screen  $P$ . Other factors are as in form A. It may be found advisable also to try two glass-tube mirrors instead of one. For the possible arrangement in that case, compare the place of the two mirrors in form B of the sonograph in figure 5.

In form C (fig. 3), a concave lens  $L_2$  replaces the mirror  $M$  of form B. Other details are as in form B. The lens  $L_2$  would have to be very small and might therefore be more difficult to obtain and adjust than the glass-tube mirror. Form C therefore seems to offer less promise of success than forms A and B.

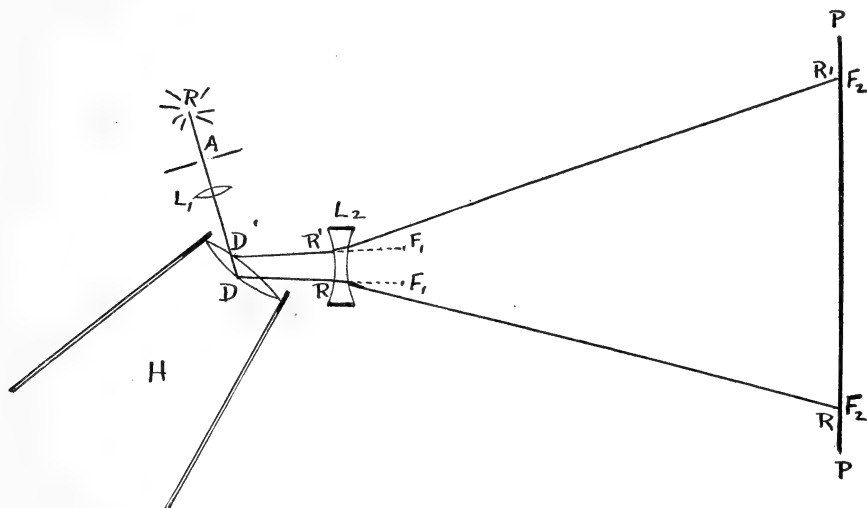


FIG. 3. PRINCIPLE OF THE SONOSCOPE, FORM C (HORIZONTAL SECTION)

*The sonograph.* The principle of the sonograph is shown in figures 4, 5 and 6. It consists of a sound-proof cylinder  $SC$  and  $S'C'$  completely cut across by an oblique opening  $OO$  comprised between two parallel planes. A ray of light  $R$  passing through the aperture  $A$  and the collecting lens  $L_1$ , all in the first section of the sound-proof cylinder  $SC$ , thence passes through a parallelogram prism  $Pr_1$  into the opening  $OO$ , through a second prism  $Pr_2$  into the second sound-proof section  $S'C'$ , where it passes through diverging lenses or mirrors to the screen or film  $PP$ . The ray  $R$  is refracted away from the perpendicular as it passes



from the prism  $Pr_1$  to the open space  $OO$ . If, at the same time voice or other sound waves are passing through the free space  $OO$ , the refraction of  $R$  will vary slightly according to the successive rarefactions and condensations caused by the varying phases of the sound waves passing through  $OO$ , thus shifting the ray or light-lever into different slightly divergent paths  $RR$  and  $RR'$ . This divergence is increased by the lenses or mirrors, thus projecting on  $PP$  an enlarged sinusoidal record of the sound waves passing through  $OO$ .

Two modifications of the second prism  $Pr_2$  will probably be found necessary in actual practice. First, it would, if unmodified in form, tend to neutralize the divergence of the light-lever  $R$ , effected by the varying air densities in the opening  $OO$ , since the refractive indices of the two prisms  $Pr_1$  and  $Pr_2$  would be reciprocal to each other for every density of air in the opening  $OO$ , while the air density in both sound proof chambers  $SC$  and  $S'C'$  remains constant. To avoid this neutralizing effect, it will undoubtedly be necessary to concave either the first surface or both surfaces of the second prism  $Pr_2$  at the point or small area where the light-lever  $R$  traverses it, the first center of curvature or concavity lying either at the point where the light-lever  $R$  emerges from the first prism  $Pr_1$  or within the open space  $OO$ . This would in effect introduce a minute concave or bi-concave lens in the second prism  $Pr_2$  at this point. Again, the second prism  $Pr_2$  may have to be doubled, with a dead air space between its two parts, in order to preserve the sound proofing of the second chamber  $S'C'$ .

In form A (fig. 4), the arrangement of lenses and focussing is the same in principle as that of form A of the sonoscope, shown in figure 1. This plan would probably necessitate the distance  $RL_2$  (from the first prism to the fiber lens) to be relatively very great in order to allow the very slight divergence of the paths  $RR$  and  $RR'$  to become sufficient for the lens  $L_2L_3$  to deal with it. How great this difficulty will prove to be in practice can be determined by trial.

In form B (fig. 5), two convex glass-tube mirrors  $M_1$  and  $M_2$  replace the lenses  $L_2L_3$  and  $L_4$  of form A. The focussing follows

the principle of form B of the sonoscope in figure 2. This form of the sonograph principle would seem to be more sure of success, since the tiny tube mirror  $M_1$  could deal with and magnify very small divergences in the paths  $RR$  and  $RR'$ , and probably need not be as far from  $OO$  as would be necessary for the lens  $L_2$  in form A.

In form C (fig. 6), a simple concave lens is substituted for the battery of mirrors or lenses of forms A and B. Otherwise it is the same in principle as form B. The difficulty of length between the prism  $Pr_1$  and the lens  $L_2$  would probably be much greater in this form than in form A. Perhaps it could be partly overcome by using an additional concave lens between  $L_2$  and  $F_1$ .

Whether or not the above suggestions prove to be practicable, the problem of approximating a perfect graphic record of sound vibrations must fulfil the conditions of eliminating all distortion, suppression, extraneous addition, reinforcement and muffling. In the final solution the light lever (or some electrical, magnetic or  $x$ -ray substitute) will probably enter. If a receiver horn and diaphragm enter in, the form must be so shaped as to have the widest range of equalized responsiveness to all forms of vibrations, and the diaphragm must be of such form and texture or so weighted as to avoid all self-vibration and unequal responsiveness. Perhaps the outer ear and ear drum of man or other animals still have suggestions to give us on these lines. If physically vibrating parts enter in, they must be of the minute order of magnitude or vibrative amplitude which allow them to vibrate fully and freely on the scale of normal sound-vibrations, and so damped or adjusted as to eliminate muffling, reinforcement and self-vibration. Mechanical construction (if any remains) must be practically perfect. Probably the final solution will come along the line of some principle which (like the sonograph principle suggested above) uses a light-lever whose initial deflection is effected by refraction as it passes through free sound-transmitting air.

# THE MANIPULATION OF THE TELESCOPIC ALIDADE IN GEOLOGIC MAPPING

KIRTLEY F. MATHER

## INTRODUCTION

The ability to use the telescopic alidade in plane-table mapping is absolutely indispensable to the geologist engaged in investigating oil and gas resources of any region. Even though he may be assisted by an "instrument man," to whom is entrusted the actual operation of alidade and table, final responsibility for the accuracy and speed of the work rests with the geologist. No geologist bent upon applying the principles of geology to the search for, and production of, petroleum may consider his training complete until he has had considerable experience using plane-table and telescopic alidade. Manipulation of the alidade is sufficiently simple to permit the tyro to grasp quickly its more obvious details, but at the same time offers opportunities for ingenuity and resourcefulness sufficiently complex to be worthy the mettle of the most expert.

It is the purpose of this paper to assemble in convenient form certain of the more successful methods of manipulating the alidade, which have been developed during the last few years by many of the workers with this instrument. It is hoped that this presentation will be sufficiently simple to enable the beginner to make use of it, and at the same time sufficiently comprehensive to be a desirable reference work for even the instrument man of wide experience. The paper does not include a description of field methods of mapping, either by traverse or triangulation; for such a description reference should be made to

the work of Wainwright,<sup>1</sup> Ransome,<sup>2</sup> Wegemann,<sup>3</sup> Stebinger<sup>4</sup> and others.

The writer is deeply indebted to his comrades of the United States Geological Survey, especially to K. C. Heald, E. Russell Lloyd and Eugene Stebinger, for much of the information assembled here. He is also obligated to the Bausch and Lomb Optical Company and to W. and L. E. Gurley for illustrations and tables reproduced from their catalogs and manuals.

#### DESCRIPTION OF THE ALIDADE

The telescopic alidade consists essentially of a telescope attached by a transverse axis to a base plate, one edge of which bears a fixed and approximately parallel relation to the line of sight, and so supported as to permit the telescope to be elevated or depressed in a vertical plane. Of the many different models on the market, that most suited to the needs of the petroleum geologist is the "miniature" or "explorer's" alidade, designed in 1909 by H. S. Gale of the United States Geological Survey, some form of which is now produced by each of the leading makers of surveying instruments. This alidade is illustrated in figure 1.

The telescope is a metal tube fitted with an object-glass at one end, an eyepiece at the other, and between the two a reticle holding cross-hairs. A diagrammatic longitudinal section of the telescope, showing the paths of light rays passing through it, forms figure 2.

The object-glass ordinarily comprises a crown lens and a flint lens so shaped and arranged as to gather the rays of light from an object and form a small inverted image in the plane of the

<sup>1</sup> Wainwright, Plane-table manual. U. S. Coast and Geodetic Survey, Rept. for 1905, App. 7, 1906.

<sup>2</sup> Ransome, F. L., The Plane-table in detailed geologic mapping. Econ. Geol. vol. 7, pp. 113-119, 1912.

<sup>3</sup> Wegemann, C. H., Plane-table methods as applied to geologic mapping. Econ. Geol., vol. 7, pp. 621-637, 1912.

<sup>4</sup> Stebinger, Eugene, Control for geologic mapping in the absence of a topographic base map. Econ. Geol., vol. 8, pp. 266-271, 1913.

cross-hairs. These lenses are contained in a separate smaller tube which may be slid in or out of the telescope tube by means of a rack and pinion turned by the focusing screw on one side of the telescope in front of the transverse axis. This is necessary to define sharply the image of distant or near objects at will, or in other words to provide a means of bringing the objects in the field of vision into focus.

The eyepiece is similar to a microscope; its purpose is to magnify the cross-hairs and the image thrown by the object-glass. It may be adjusted to suit the eye of the individual observer by twisting the knurled ring at the end of the telescope tube. This

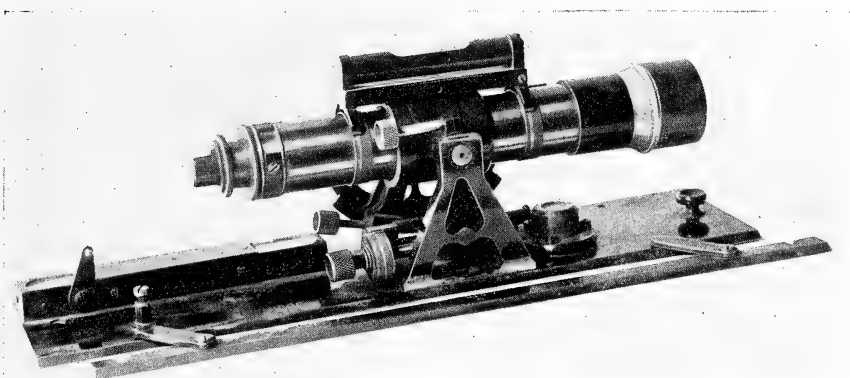


FIG. 1. THE GALE ALIDADE WITH STEBINGER GRADIENTER DRUM ATTACHMENT AND DETACHABLE PARALLEL RULE; STRIDING LEVEL IN PLACE AND COMPASS NEEDLE RELEASED. (PHOTOGRAPH FROM U. S. GEOLOGICAL SURVEY.)

shifts the eyepiece toward or away from the cross-hairs. Once properly adjusted there is no reason for changing the position of the eyepiece unless the instrument is used by another observer.

If the image formed by the object-glass is not in the same plane with the cross-hairs, any movement of the eye is likely to cause an apparent movement of the image with respect to the cross-hairs. This is called *parallax*. The effect is similar to that produced in looking through a window, where any movement of the eye causes an apparent movement of objects outside. Parallax may render accurate work impossible. To remedy it the image and the cross-hairs must be brought into the same plane. Two steps are necessary.

(1) Point the telescope toward the sky and move the eye-piece in or out until the cross-hairs are as well defined as possible, i.e., in perfect focus. . . .

(2) Direct the telescope to the object and focus the object-glass as usual, keeping the eye on the cross-hairs until the image appears in sharp focus. Test by moving the eye from side to side, and if necessary move the object-glass slightly until parallax disappears.

The more accurate the work the more care should be used to eliminate parallax, while the higher the power of the telescope the more difficult it is to do this.<sup>5</sup>

At the ocular end of the eyepiece is a fixed prism which deflects the rays of light at right angles to their line of passage through the telescope and at the same time produces an erect image of the field. All observations are to be made while the operator is

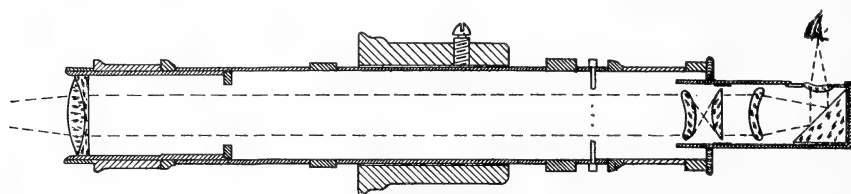


FIG. 2. DIAGRAMMATIC LONGITUDINAL SECTION OF ALIDADE TELESCOPE;  
PATHS OF LIGHT RAYS INDICATED BY BROKEN LINES

looking directly down into the eyepiece prism. Some alidades are fitted with a "periscope" or tubular roof above the eyepiece prism in which is housed a lens for the reversal of the image. When this is wanting, images in the field appear right side up but reversed from right to left. To keep maximum illumination of an undistorted field as observed through a roofed prism entails precision grinding of the highest order of merit; this is obviously very expensive so that there exists some doubt as to whether it actually pays to correct the relation of the elements of the field in this particular.

The magnification of miniature alidades is ordinarily 16 or 20 diameters.

<sup>5</sup> J. C. Tracy, *Plane Surveying*. John Wiley and Sons, New York, 1907, pp. 555-6.

The cross-hair ring, or reticle, is placed so as to be at a principal focus of the object-glass as well as at a focus of the eyepiece. Its position is indicated by four screws or capstans on the outside of the telescope tube. The cross-hairs are spider webs, or very fine platinum wires, almost invisible to the unaided eye. They are generally four in number and are fastened immovably with shellac to the brass ring before it is inserted in the telescope. Two of the hairs cross the center of the ring at right angles to each other; their purpose primarily is to define the line of sight. The other two are parallel to one of these and spaced equidistant on either side of it; they are the *stadia hairs* and are used primarily for measuring distances. In the Gale design of alidade, none of these hairs are adjustable with respect to each other, but the whole reticle may be moved by means of the four screws which hold it in place.

It is very important for purposes of adjustment to understand how the capstan screws control the movement of the cross-hair ring. . . . The holes in the telescope through which the screws pass are not threaded; on the contrary, they are a little larger than the screws, so that when the latter are loose the whole ring may be turned slightly by moving the four capstan heads simultaneously around the outside of the telescope until one cross-hair is vertical and the other horizontal. When the capstan screws are tight, each screw presses a curved washer (shown in the photograph) against the outside surface of the telescope. When one screw is loosened and the opposite screw tightened, the whole ring is drawn toward the tightened screw (since the holes in the shell of the telescope are smooth) until the loose screw and its washer are brought into contact again with the outside of the telescope. Notice that before tightening one screw the opposite screw should be loosened, otherwise the ring cannot move and the screw-thread may be stripped. By loosening the lower screw and tightening the upper screw, the whole ring may be drawn upward, or by reversing the process it may be drawn downward. Likewise by working the side screws in a similar manner, it may be drawn to one side or the other. All this may be done without turning the ring, i.e., one hair may be kept vertical, the other horizontal.<sup>6</sup>

<sup>6</sup> J. C. Tracy, loc. cit., p. 550.

The telescope tube is inserted in a short sleeve at its mid-length, which forms a part of the transverse axis by means of which vertical oscillation is made possible. The telescope is mounted revolvably between 180-degree stops in this axis-sleeve and is prevented from turning on its longitudinal axis in the process of focusing either by a plunger at the under side or by a clamp ring screwed at one end of the sleeve. At either side of this axis-sleeve the telescope is surrounded by a "red metal" collar, accurately turned to the axis of rotation defined by the sleeve. These collars are for the support of the striding-level by means of which the telescope is brought into the plane of the horizon. The striding-level is removable and when not in use is held in a corner of the base plate by a binding post. A similar post is attached to the top of the axis-sleeve and when the striding-level is put in place for observations, as in figure 1, it is snapped down over the shoulder on this post, which merely prevents it from falling off in case the alidade is tilted and should not support it in any way. The wyes, trued to the same angle, at either end of the bubble glass then rest on the metal collars.

The striding-level itself is a glass vial, partially filled with a non-freezing liquid, ground on the inside to the arc of a circle with long radius.

The more uniform this curvature is throughout the length of the tube the more regular will be the motion of the bubble, and the greater the radius of curvature the greater the sensitiveness of the bubble. Within reasonable limits the more sensitive the bubble the more perfect the work, though a very sensitive bubble may be too unsteady for many purposes; on the other hand a sluggish bubble, though it may give the appearance of steadiness to an instrument, and an impression that it "keeps" its adjustment, is incapable of accurate work. . . .

The line tangent to the circular arc of the tube at its middle point, or a line parallel to this tangent, is called the *axis of the bubble-tube*. When this axis is horizontal the bubble will be in the center of the tube. Should the axis become slightly inclined the bubble will move toward the higher end of the tube in proportion to the angle made by the axis with the horizon. The glass tube is usually graduated on top by marks 0.01 feet (or 2 mm.) apart. The value of a level-bubble is usu-

ally expressed by the change which takes place in the inclination of the axis when the bubble moves over a single space. Thus in a 1-minute level for a displacement of one division the inclination changes 1 minute, and in a 20-second level it changes 20 seconds.<sup>7</sup>

Ordinarily, the alidades in use by geologists are fitted with 60-second levels, but it is preferable where possible to use a 20-second level, a change which at low cost adds greatly to the possible accuracy of the work.

The telescope and axis-sleeve are carried on standards about two inches high to permit a reasonable vertical swing of the telescope. The transverse axis projects beyond the bearings which cap these standards and is gripped on the right by the vertical clamp. This is tightened or loosened by the knurled screw, set close to the top of the right hand standard. When loosened, the telescope swings freely through an arc of about 45 degrees in the plane at right angles to the transverse axis. When tightened, the swing of the telescope is limited by the play of the clamp arm, a downward extension of the clamp proper. In one style of miniature alidade, this arm is held by a horizontal spring against the point of a horizontal tangent screw working through the lower part of the telescope standard. In another model this arm is expanded, and itself carries the tangent screw and horizontal spring bearing against a stud fixed to the inside surface of the right hand standard. In either, the rotation of the tangent screw causes the telescope to be slowly elevated or depressed. The screw is therefore spoken of sometimes as the fine adjustment or micrometer screw. A graduated drum may be attached to this screw, as in figure 1, which as explained later may be used in the measurement of distances or the determination of vertical angles. When thus equipped the tangent screw is known as the *gradienter screw*. Or if the special gradienter drum provided with a celluloid index, as suggested by Eugene Stebinger, United States Geological Survey, is attached, it is frequently referred to as the *Stebinger drum and screw*.

<sup>7</sup> J. C. Tracy, loc. cit., p. 544.

Fixed to the opposite end of the transverse axis and attached just outside of the left hand standard is a graduated arc, generally of about 130 degrees duration, by means of which vertical angles are measured. It is therefore referred to as the *vertical arc*. It moves past a shorter arc of similar curvature, which carries the vernier scale and is adjustable by means of a horizontal screw working through the left hand standard in much the same way as does the micrometer screw on the right standard.

The base plate is firmly attached to the telescope standards and is primarily intended to form a straight edge, parallel with the line of sight through the telescope and maintaining that fixed relation no matter in what direction the instrument is pointed. To facilitate the use of the straight edge, the right side of the plate is beveled and graduated in linear measure; it is known as the *fiducial edge*. In the miniature alidades there is attached to one corner of the base plate a compass box, or *declinatoire*, housing a compass needle which has a possible oscillation of about 10 degrees. The compass is not intended for the reading of angles of departure from magnetic north, but solely for the designation of the magnetic meridian; therefore the only markings are the zero points at either end of the needle. The needle is either of the tubular or the steel bar variety, mounted generally on a sapphire-tipped pivot, and provided with clamping device and adjustable balance. The latter must be adjusted by the user for different latitudes by sliding it along the needle until it is properly balanced. A declinatoire so constructed as to make the needle easily accessible is therefore preferable. There is also fixed to the base plate, generally near the objective end of the telescope, a *bull's eye level* by means of which the plane table on which the alidade is resting may be quickly brought into an approximately level attitude.

An "extra" attachment which has proved to be a great time- (and therefore money-) saver is the *parallel rule*, shown in figure 1. A brass straight-edge,  $\frac{1}{2}$  inch wide and as long as the alidade base, carries two brass bars, 1 or  $1\frac{1}{4}$  inch long, pivoted near either end, with the pivot centers in a line parallel to the straight edge. Set in the free end of each short bar is a round

lug which fits into a circular hole bored in the base plate near its margin. The centers of these holes are in a line parallel to the fiducial edge, and the short bars are of equal length. Therefore the removable straight-edge, when put in place, is parallel to the fiducial edge and may be shifted close to it or out away from it without losing its parallelism. In "lining-in" a distant station, all the time involved in getting the fiducial edge exactly on the occupied station point is saved. The line of sight is mechanically shifted in parallel position to the proper place on the map. Similar holes may be bored near the left side of the alidade base, and the same straight-edge attached there for work close to the left margin of the table, but if that change is made, the table must be re-oriented because of the probable change in the relation between the line of sight and the ruler edge. The parallel rule, when detached, may be conveniently carried in a pocket sewn across one edge of the alidade case.

The complete instrument weighs about 3 pounds, stands between 3 and 4 inches in height, and is 10 to 12 inches in length. It is fitted into a sole-leather case with shoulder strap for carrying in the field.

#### MANIPULATION OF THE ALIDADE

##### *To determine bearing*

In traversing with plane table and alidade, the location of an unplotted point is determined by its direction and distance from another point which has previously been plotted on the plane table sheet. Instead of determining this direction in terms of a compass or angle reading, to be later drawn on the map in the office, as is done with transit or theodolite, the determination and the plotting of the bearing to the distant point are accomplished by a single operation. This makes necessary the accurate orientation of the plane table sheet so that the lines drawn on it will, whenever the plane table is set up for use in the field, be parallel to the position which they occupied at every preceding set-up.

*Plane table orientation.* Orientation of the plane-table sheet is ordinarily accomplished by means of the magnetic needle housed in the compass box attached to the base of the alidade. The fiducial edge of the alidade base is placed along a line ruled on the plane table sheet, and the needle liberated from its rest so that it swings freely in its box; the table is then rotated until the needle points to the north and south marks at either end of the compass box. Thereafter, whenever the same alidade is placed on the same side of the same line so that the same edge of its base coincides with the line, and by rotating the table the freely vibrating needle is made to come to rest at the same point, the sheet is in approximately parallel position. The orientation line ruled on the plane table sheet should extend the full length of the alidade base, or should consist of two shorter lines, three or four inches in length, drawn to each extremity of the base. An arrow should be sketched at the north end of the line or lines; the compass box is so attached to the alidade that when the needle comes to rest in the line of the marks at its ends the line of sight through the telescope leads approximately toward magnetic north.

Although of course not necessary, it is very desirable and universally customary so to draw the orientation line that the sides of the plane-table sheet coincide with the four cardinal directions. This may be accomplished in several ways, a few of which will be mentioned here. In many parts of the country, the public roads have been accurately surveyed along section lines; commonly the fences have been similarly placed in a true north-south or east-west direction; or again, section corners may be so situated that one corner-post—or a flag placed directly above it—may be seen from another. If the plane table can be set up in the line thus determined by road or fence or land net, the ruler-edge of the alidade should be placed along the margin of the plane table sheet, or along the line previously drawn to represent the meridian of the map, and the table rotated until the line of sight through the telescope falls along the visible line thus defined. The table locked in that position, the alidade is moved to the desired part of the sheet and turned until the

compass needle comes to rest in the line of its indicators. The orientation line is then ruled along the alidade base. The angle between that line and the meridian of the map will be determined by the local magnetic declination as modified by any divergence which may be present between the line of sight of the alidade, the fiducial edge of the alidade base, and the line defined by the compass needle and its indicators. These three lines need not be parallel; the work will not be affected by divergence between them.

Another method of orienting the table before drawing the orientation line makes use of a Brunton or other compass, care being taken to make allowance for the departure of magnetic from true north, and depends upon previous knowledge of the magnetic declination in the region.

Or, again, it may be necessary or desirable to draw the orientation line on the plane-table sheet before it is oriented for the first time. It must then be assumed that the line of sight, the compass line, and the alidade straight edge are parallel; the error in orientation thus involved will in most cases be of no consequence. The orientation line is plotted so that the angle between it and the meridian line is equal to the magnetic declination. This angle may be scaled off by means of a protractor, or if more accurate drafting is desirable, a trigonometric function may be used. Draw a line 10 inches long in the desired position of true north; at one end erect a perpendicular such that its length in inches is 10 times the tangent of the angle of declination; connect the other end with the end of the perpendicular by a line which is the desired orientation line. This is more accurate than plotting the angle with a protractor which has a radius of only 3 or 4 inches for in that case any error in plotting is greatly multiplied when the line is extended to the necessary length of 12 or 15 inches.

The whole matter of accurate situation of the orientation line is of slight importance when working upon a plain sheet, but is of the greatest importance if the work is to be done upon a sheet on which the land net has been previously plotted, or upon a base map prepared by other surveyors, as for example an enlarge-

ment of a portion of a United States Geological Survey topographic map or a Land Office map.

The use of the magnetic needle for orientation of a plane-table sheet requires the utmost care. The length of the needle from its pivot to either end is only  $1\frac{1}{2}$  to 3 inches, and lines will frequently be drawn on the map which are much longer than that. Errors in observing the needle may therefore be multiplied during the progress of the work and thus may become of more than trivial importance. Careful attention should be paid to see that the needle is swinging freely; a pocket magnifier should be used in observing its position with respect to the indicators; observation should be made from directly behind the instrument so that the observer sights along the needle from above rather than from the side.

In many instruments the needle is not perfectly straight, or the two indicators and the needle pivot are not in a straight line; it is then best to regard only one end of the needle, being careful always to use that end and not the other. Or, again, the needle points may be blunt and the indicators of considerable width; in that case select a definite relationship of needle point to marker and adjust the table or alidade so that the needle always returns to that relationship each time the map is oriented.

The surveyor must, moreover, be always on guard lest steel or iron bodies in proximity to the compass box deflect the needle. Articles about his own person should receive his attention; he should stand so that his pocket knife is at least a foot from the needle; a Brunton or other compass must be kept at least 3 feet distant and must, therefore, be removed from the belt before attempting to orient the table; the margin of safety for a geologic hammer is a little less than 2 feet, and it may therefore be left in the belt if carried in the rear and if the surveyor stands well away from the table in observing the needle; a harmless appearing, leather-covered metal binocular or monocular case, if permitted to come within 2 feet of the needle, may lead to the erroneous conclusion that one is endowed with a superabundance of personal magnetism. Metallic bodies in the general vicinity

of the plane table may deflect the needle and introduce grave errors into the work. The table should never be set up for compass orientation within 10 feet of a wire fence, within 15 feet of a pump-jack, less than 10 feet away from a pipe-line, buried or on the surface, closer than 10 feet to a railroad track, or nearer than 20 feet to an automobile.

The plane-table sheet may also be brought into correct orientation without the use of the compass needle by means of fore-sight lines. This necessitates the planning of one's work for days or even weeks in advance, but should be used in all triangulation work and may be used in orienting the table at any set-up where for some reason compass orientation is unwise. Assume that two stations are clearly visible, the one from the other, and that the table is set up in correct orientation at one, while the other has not yet been occupied. A line, the fore-sight, is drawn from the point representing the occupied station in the direction of the distant objective. It should be drawn the full length of the alidade base, extending from the plotted point away from the uncharted as well as toward it, even though the point when plotted will be only an inch or two away from the occupied station. Or if preferred, the fore-sight line may be discontinuous, covering the estimated location of the distant station on the map and including a line an inch or so in length at either end of the alidade straight edge. When, later, the station to which the fore-sight line has been drawn is reached in the progress of the field work, the table should be approximately oriented with the eye, the alidade base placed along the fore-sight line so that the telescope points back toward the old station, and the table rotated until the distant signal is bisected by the vertical cross hair of the alidade. The most likely place for error to enter into this manipulation is in the adjustment of the alidade base to the ruled fore-sight line; a pocket magnifier should be used in the placing of the alidade, if the most accurate results are desired.

Still another method of orientation makes use of the Baldwin Solar Chart. The angle between the apparent position of the sun and true north is graphically determined by means of this chart which is so constructed that when turned until the proper

pivot point on an arrow and the "sun-time point" on a latitude arc are on a line parallel to the shadow cast by a plumb-line upon a level table the arrow points true north. A copy of this chart and full directions for its use may be found in Topographic Instructions of the United States Geological Survey, pp. 136 to 141.<sup>8</sup>

*Lining in the station.* After the table has been properly oriented at a station, the location of which has been plotted on the map, the bearing of any visible object may be drawn directly. The alidade is moved until the straight edge touches the side of the needle-hole or pencil dot representing the occupied station and the vertical cross-hair in the telescope bisects the distant object, the bearing of which is desired; a line drawn along the straight edge will then represent the compass-bearing plotted to position on the map under construction.

The best method to pursue in lining-in a distant station is to grasp the ends of the alidade base with either hand; shift the instrument until the line of sight through the telescope falls upon the desired objective and the fiducial edge rests within an inch or two of the dot locating the occupied station; then move the alidade diagonally forward and to the right, keeping the vertical cross-hair on the distant object, until the ruler edge touches the proper point. If the alidade is equipped with a parallel-edge ruler, it is only necessary to place the instrument somewhere near and to the left of the plotted point in such a position that the vertical cross-hair cuts the distant station; then push the parallel straight-edge outward until it touches the proper point. Some surveyors make it a practice to stick a needle vertically into the plane table at the point representing the occupied station, and to pivot the alidade on the needle when lining-in a station. This practice is not recommended. Although it is an easy way for the novice to increase his speed, it involves inaccuracies of considerable import. If the needle is inserted far enough to hold its upright position, it makes a hole several times as large as necessary; the point becomes a space which on

<sup>8</sup> Government Printing Office, Washington, D. C., 1918; price 35 cents.

the customary scales represents an area on the ground, 30 to 60 feet in diameter.

Lines representing bearings should be drawn with the chiseled edge of a 9-H pencil, being careful always to hold the pencil at the same angle and to see that the contact of rule and paper is perfect. By placing the ruler edge in a position tangential to the tiny circle formed by needle-hole or dot, the line when drawn should exactly cut the center of the "point." If the distant station is subsequently to be occupied and orientation there is to be by back-sight, the fore-sight line should be the full length of the alidade base; if not, the fore-sight line may be short, covering only the estimated position of the point. It is better not to draw lines through the dot or needle-hole representing the occupied station; break the line for a fraction of an inch on either side.

#### *To measure distance*

Distances are directly determined with the telescopic alidade by means of the stadia hairs and rod. Stadia work depends upon the hypothesis that the sizes of objects required to produce an image of fixed size in the telescope are directly proportional to their distances from the point over which the telescope is set. This hypothesis is not rigidly correct, but the theoretical error is small and the practical error negligible. The limits of the image in the telescope are fixed by the parallel stadia hairs in the reticle. The object most convenient to use is a graduated rod. In the alidades commonly used by the geologist, the stadia hairs are so adjusted that the ratio between the distance from the telescope to the rod and the distance intercepted on the rod by the upper and lower hairs, when the rod is held at right angles to the line of sight and to the hairs, is as 100 to 1. If the rod is 100 feet from the instrument, the outer hairs appear to subtend 1 foot upon it; if 1200 feet distant, 12 feet of the rod will appear between them (see figure 3). Moreover, the middle cross hair in the reticle is placed as nearly as possible equidistant from the outer two. Therefore, the distance subtended on the rod by the middle hair and either outer hair is  $1/200$  the distance of the

rod from the telescope. In some alidades, "quarter hairs" are placed so that they bisect the spaces between the outer and middle hairs. The ratio for them is, of course, 1: 400; with an instrument so equipped distances up to 400 times the length of the rod may be read directly. Sketches showing the relation of a stadia rod to the field of view at different distances are shown in figures 4, 5 and 6.

In practice, then, it is necessary only to raise or lower the telescope until the two stadia hairs appear to rest on the rod, one intersecting a primary division and the other falling across a divided foot. Read the intercept and multiply that distance by 100 if the outer hairs were used, by 200, if the middle and one of the

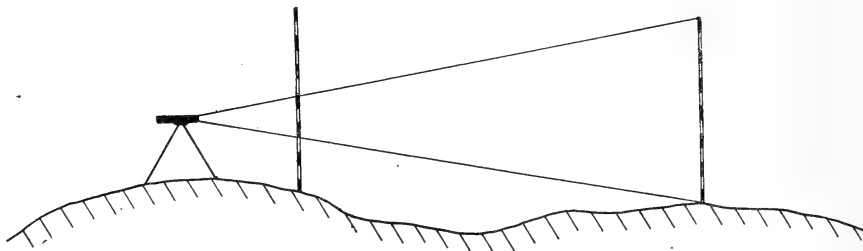


FIG. 3. DIAGRAM ILLUSTRATING THE STADIA PRINCIPLE

The diverging lines representing the projection of the stadia hairs form intercepts on the rods proportional in length to their distance from the instrument.

outer hairs were used, or by 400, if the "quarter hairs" were read. Use the most distant hairs the intercept of which may be read, for otherwise the observational error is multiplied by 2 or 4, as the case may be. Also place the hairs as near the top of the rod as possible so as to minimize the error of refraction.

As a matter of fact, the distance in the line of sight to the rod, thus determined, is not measured from the center of the instrument but from a point in front of the telescope objective at a distance equal to  $F$ , the focal length of the objective. Therefore the distance from center of alidade to rod is represented by the formula

$$D = 100s + F + c,$$

where  $s$  is the intercept on the rod between the outer hairs, and  $c$  the distance from center of instrument to objective.  $F + c$  is practically a constant for a particular alidade, as it varies only

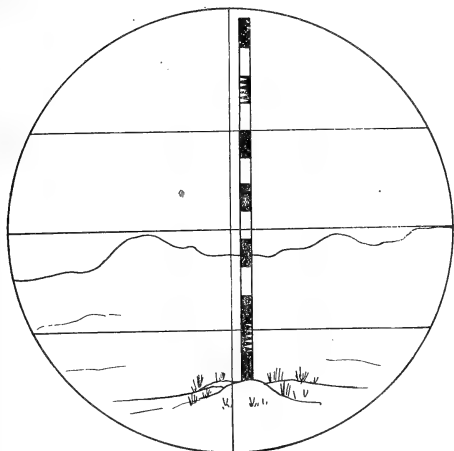


FIG. 4. STADIA ROD IN THE FIELD OF VIEW AT A DISTANCE OF 720 FEET

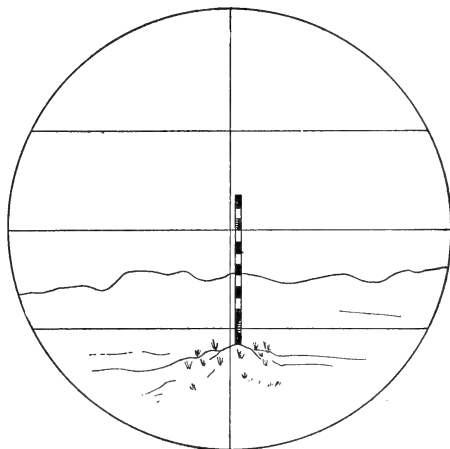


FIG. 5. STADIA ROD IN THE FIELD OF VIEW AT A DISTANCE OF 1740 FEET

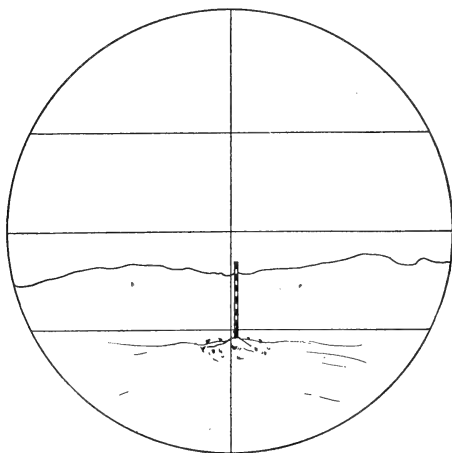


FIG. 6. STADIA ROD IN THE FIELD OF VIEW AT A DISTANCE OF 3360 FEET

with the focusing of the instrument. For ordinary purposes it may be taken as 1 foot, a space so short as to be altogether negligible in most work undertaken by the geologist.

*Long sights.* Occasionally, it is necessary to measure distances greater than 200 times the rod length with an alidade equipped only with three stadia hairs. Several different methods of procedure are available; the choice of the one to use depends upon the equipment of the instrument, the geographic environment, and the custom of the individual surveyors. Some of the methods are in effect schemes to provide a longer rod. Others depend upon trigonometric principles. The method numbered 5 is probably best suited to the more common conditions met in geologic mapping.

1. Rotate the telescope 90 degrees in its sleeve so that the stadia hairs are vertical instead of horizontal. Signal rodman to mark his station with a flag or to select a certain sapling or post for his station. Place one hair on the station and signal rodman to move at right angles to the line of sight until the rod, held vertically, is in line with the other stadia hair. The rodman will then measure the distance horizontally on the ground from his second position to his first, using the rod as a measuring stick, and report the result to the instrument man. Distances of 4000 to 7000 feet may be determined with a fair degree of accuracy by this method. It may be used to advantage only when the two men are able to communicate freely by signals such as the two-arm semaphore code.

2. Rotate the telescope as before. Signal rodman to hold rod horizontally and to be prepared to move laterally so that the base of the rod will occupy the point now occupied by its top. Intersect base of rod with one stadia hair. Signal rodman to move over in the desired direction a sufficient number of rod-lengths so that the other stadia hair will finally intersect the rod. Read intersection; add the number of feet indicated by the length of the rod multiplied by the number of moves; multiply by 100 or 200 depending upon which hairs were used.

3. If instrument is equipped with a Stebinger grader drum attached to the fine adjustment screw, proceed as follows: Place bottom hair on lowest visible primary division of the rod; read and record Stebinger. Turn Stebinger drum until middle hair rests on the top of the rod; read and record Stebinger. Take

the difference of the two Stebinger readings; turn an equal number of divisions in the direction which brings the middle hair down onto the rod; observe the number of feet between the top of the rod and the intersection of the middle hair. Add this to the length of the rod which was above the bottom hair at the first reading; the sum multiplied by 200 is the horizontal distance. For example:<sup>9</sup> 12 feet of the rod are entirely visible and the middle hair is well above the rod when the bottom hair rests 12 feet below its top. In that position the Stebinger drum reads 24. Turn down until middle hair touches the top of the rod; Stebinger reading is now 60. The difference between the two readings is 36. Turn down 36 divisions more, to 96. The middle hair now intersects the rod 3.4 feet below its top. The horizontal distance is  $200 \times (12 + 3.4)$  or 3080 feet.

4. If instrument is equipped as in 3 and there is at hand a table, previously prepared for this particular instrument, showing Stebinger factors,<sup>10</sup> i.e., the differences in elevation at the unit distance of 100 feet corresponding to the vertical swing of the telescope denoted in divisions of the Stebinger drum, proceed as follows: Place one hair on the top of the rod; read and record Stebinger. Turn down until that hair cuts the lowest visible primary division of the rod; read and record Stebinger. Take the difference of the two readings. Repeat for each of the other two hairs. The three results should check. Select from the table the Stebinger factor corresponding to that number of divisions. Note the number of feet passed over on the rod; multiply it by 100 and divide by the factor. The result is the horizontal distance. For example: 13 feet of the rod are visible. With the middle hair resting on the top of the rod, the Stebinger reading is 62. When the middle hair is turned down to the primary division 13 feet lower, the reading is 106. Difference of the two readings is 44; corresponding factor is 0.4111; horizontal distance is  $1300 \div 0.4111 = 3160$  feet.

<sup>9</sup> This, and the following examples apply only to those instruments in which a clock-wise rotation of the Stebinger drum depresses the objective end of the telescope.

<sup>10</sup> The preparation of such a table and the mathematical principles on which it is based are discussed in subsequent pages of this paper.

This method is frequently employed by ingenious surveyors to good advantage in determining distances without the use of the stadia rod. Any two points, one above the other, at known distances apart suffice; two flags at a measured interval, the crown plate and girths (commonly eight feet apart) of a standard derrick, the eaves and lower copings of a church tower, are listed merely as suggestions. If the location of such a target is plotted, the surveyor may "shoot himself in," with a fair degree of accuracy, at any point from which it is visible.

5. If alidade is equipped as in 3, an alternative method which may be used is as follows: Place middle cross hair on top of rod; read and record Stebinger, denoting the record as *A*. Turn down until middle hair intersects the lowest visible primary division; read and record Stebinger (record *B*). Turn down until top hair rests on top of rod; read and record Stebinger (record *C*). Compute distance by the formula

$$D = 200r \frac{C - A}{B - A},$$

in which *D* represents the distance, *r* the length of the rod above lowest visible primary division, and *A*, *B*, and *C*, respectively the three readings of the Stebinger drum. For example: a 13-foot rod is entirely visible. The middle hair on top of rod gives a Stebinger reading of 31; middle hair on bottom of rod gives a reading of 54; top hair on top of rod gives a reading of 78.

$$\text{Distance} = 200 \times 13 \times \frac{78 - 31}{54 - 31} = 5300 \text{ feet.}$$

The formula may be more easily recalled if one has grasped the principle upon which it is based. The Stebinger difference, *C* - *A*, is theoretically a constant, the measure of the angle between the rays converging from the top and middle cross hairs to the focus of the telescope. If the rod at the distant point were of sufficient length, the intercept subtended by this angle could be read and, multiplied by 200, would give the distance to the rod. That is, if *i* be taken to mean the length in feet of that hypothetical intercept,

$$i = D \div 200.$$

But

$$i : r :: C-A : B-A,$$

for the Stebinger difference  $C-A$  is the measure of the angle defined by the chord  $i$  and  $B-A$  is the measure of the angle defined by the length of the rod at the same distance. Therefore,

$$(D \div 200) : r :: C-A : B-A,$$

or

$$D = 200r \frac{C - A}{B - A}.$$

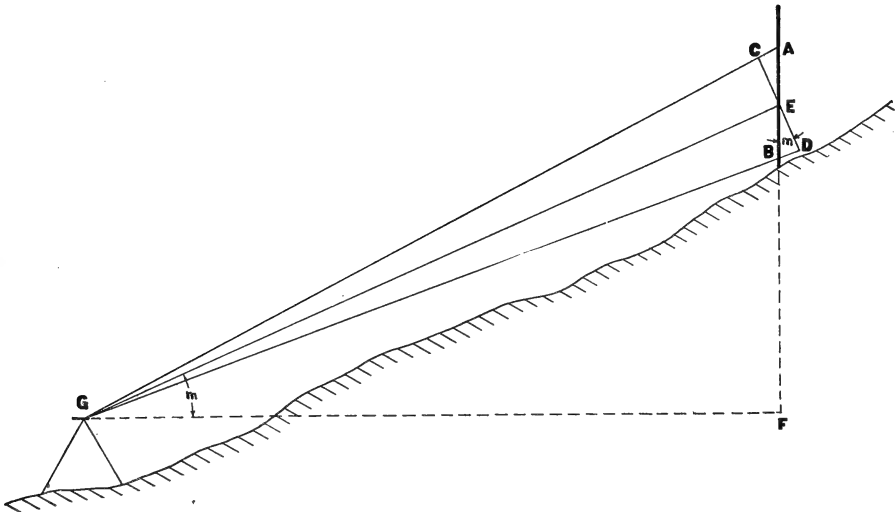


FIG. 7. DIAGRAM ILLUSTRATING THE STADIA PRINCIPLE APPLIED TO INCLINED SIGHTS

*Inclined sights.* This discussion of the measurement of distances with the stadia has been based on the assumption that the rod is always held perpendicular to the line of sight and that the desired distance is to be measured along that line. As a matter of fact, most of the sights in stadia work are taken not on a level, but on a slope or inclination, as suggested in the diagram, figure 7. Consequently if the rod is held vertically, the stadia intercept is somewhat more than it would be when held perpendicular to the line of sight, and an element of error is intro-

duced. This error amounts to 1 per cent of the distance for a gradient of 8 degrees, 2 per cent for 11 degrees, and 3 per cent for 14 degrees. It may obviously be corrected by tilting the rod so that it is perpendicular to the central visual ray from the telescope. This may be accomplished by attaching a short pointer to the rod at right angles to its face and aiming this pointer at the instrument when the sight is taken. It is, however, difficult to hold the rod steadily in this position and this corrects only one of the two discrepancies. It is therefore customary to hold the rod vertical no matter what the angle of slope may be and make the correction in the tables for distance and elevation. The second discrepancy is due to the fact that the distance to be plotted is the horizontal distance from telescope to rod, not the inclined distance. So far as plotting is concerned, this discrepancy, and therefore the angle of inclination, must be fairly large before it need be taken into account; how large depends upon the scale of the map, but for most work it may be neglected for all angles of less than 3 degrees. With an angle of  $5\frac{1}{2}$  degrees this discrepancy amounts to about 1 per cent, which for a distance of 1000 feet is little more than the diameter of a needle hole on a scale of 1: 31,250.

The stadia tables ordinarily used include the correction for horizontal distance of inclined sights. In practice, such tables should be consulted before plotting distances determined by sights which depart more than 3 degrees from the horizontal. Reference to the accompanying diagram, figure 7, will make clear the mathematical formula upon which the correction tables are based. In the diagram,  $AB$  represents the intercept on the rod held vertically,  $CD$  the intercept on the rod held perpendicular to the line of sight from  $G$ ,  $GE$ , the distance from table to rod in the line of sight, and  $GF$  the horizontal distance from set-up to station. The angle of inclination of sight and the equal angle between the two positions of the rod are indicated by  $m$ . By trigonometry,

$$CD = AB \cos m$$

and

$$GF = GE \cos m.$$

But

$$GE = 100 CD = 100 AB \cos m;$$

therefore, by substitution,

$$GF = 100 AB \cos^2 m,$$

by means of which the horizontal distance may be computed from the rod intercept and the angle of inclination.

The correction to be applied to the observed distance on inclined sights may be determined without reference to tables or formulae by means of the Beaman stadia arc (see fig. 11) an attachment for the mechanical solution of the stadia problem, which will be described in greater detail in a subsequent paragraph. The arc carries two scales, a multiple scale and a reduction scale, having coincident zero points marked 50 and 0, respectively. The reduction scale is, of the two, the more distant from the adjustable index and gives percentages of correction that may be used to reduce observed stadia distances to horizontal. The adjustable index should be set opposite the zero of the reduction scale when the telescope is level. To get the necessary correction, simply read the same scale with the line of sight cutting the distant station. Reading to the nearest per cent is usually sufficient. For example: the reduction scale reads 3 with an observed rod intercept of 16.2; then 3 per cent of  $1620 = 48.6$ ;  $1620 - 48.6 = 1571.4 =$  corrected horizontal distance.

*Location of stations.* The distance thus determined by stadia is scaled off on the line ruled in the direction of the rod station from the point representing the occupied station. The proper method is to place the fractional scale division on the plotted point and prick the new location with the needle, or mark it with a well sharpened pencil, at the even division at the end of the scale. This operation should be performed with the greatest care and preferably with the assistance of a pocket magnifier; more closure errors are to be attributed to careless plotting than to any other cause. If a needle is used, do not try to puncture a hole clear through the paper; push the needle point just far

enough into the paper to make a permanent indentation, being careful to hold the needle vertically.

*Accuracy of the stadia method.* The telescopic alidade and stadia rod are to be looked upon as instruments of precision; distances are not estimated, but accurately determined in well-conducted stadia work. Although essentially intended to secure rapidity rather than accuracy, the stadia method employed with due care to eliminate the chief sources of error is capable of attaining a high degree of accuracy.

Perhaps some of the most interesting results obtained with stadia, as showing its precision, were those obtained by Mr. J. L. Van Ornum in taking topography on the international survey of the Mexican Boundary. The whole of the boundary line was measured with the stadia, and a large portion of it by the chain, and always tied in by a system of accurate primary triangulation. Corresponding distances were found by stadia and chain and compared with the known distances as obtained by triangulation, with the following results:

Of five different stretches measured by the three methods, the total distance shown by triangulation was 99,110 meters, by stadia 99,025 meters, by corrected chain 99,041 meters. . . . Other sections of the line were measured by stadia and triangulation, but not by chain. In all there were measured 182.5 miles by stadia which were triangulated and in which the total difference in length was plus 50 meters, or 1 in 5837. It may be noted that the chained distance was marked corrected chain, because in six measurements of the chained distance, dropping or omission of chain-lengths occurred which were detected in every instance by the stadia.<sup>11</sup>

#### *To determine differences in elevation*

Methods of determining differences in elevation by means of the telescopic alidade are even more numerous than those in vogue for measuring distances. The good instrument man will know several different methods and select the one best suited to the particular sight, depending upon the accuracy required, the inclination of the sight, the equipment of the instrument, and

<sup>11</sup> H. M. Wilson, *Topographic Surveying*. John Wiley and Sons, New York, 1910, pp. 241-2.

the necessity for speed. The more commonly used methods will be described in the order of their simplicity.

1. *Direct readings on the rod.* Occasionally the difference in elevation between plane table and rod is so slight that with level telescope the middle cross hair intersects the rod. The vertical distance from the bottom of the rod, or from any other selected point on it, to the point of intersection may be read directly from the graduations on the rod's face. Care must be exercised to prevent the confusion of the top and bottom stadia hairs with the middle cross hair. It is the visual ray projected by the middle hair that is parallel to the striding level and therefore is horizontal when the level bubble is centered.

But, suppose that when the instrument is level, the middle hair falls above or below the rod while one of the other horizontal hairs cuts the rod. In practice it is customary first to read the rod intercept for distance and second to determine the vertical difference between instrument and rod; therefore, the operator has just measured the vertical distance between the visual rays projected by the cross hairs at the position occupied by the rod. The bottom hair, in figure 8, for example, cuts the rod at a point, the distance of which below the point where the middle hair would intersect the rod, were the rod long enough, has just been determined. Similarly, the top hair in figure 9 intersects the rod at a known distance above the middle hair. Hence, if any of the three hairs rests on the rod when the telescope is level, the vertical difference between instrument and rod may be measured directly.

Examples are illustrated in figures 8 and 9. In the former, the horizontal distance has been read as 1050 feet and with level telescope the bottom hair intersects the rod 9.6 feet above its base, which is therefore 14.85 feet below the elevation of the instrument. In the latter, the horizontal distance has been determined as 1960 feet and with level telescope the top hair intersects the rod 1.8 feet above its base, which is therefore 8 feet above the alidade.

In practice it is only necessary to record the horizontal distance and the rod intersection, noting which hair intersects the

rod, with level sight. The vertical distance can be determined later by addition or subtraction.

2. *The step method.*<sup>12</sup> The same principle may be extended to cover a much larger range of circumstances. Suppose the rod is so far below the elevation of the alidade that with level sight all three hairs project rays slightly above the top of the rod. Note where the middle hair intersects any fixed object in the field—a point on a nearby tree, or a certain rock on the distant hill-side. Turn down the instrument until the top hair intersects the

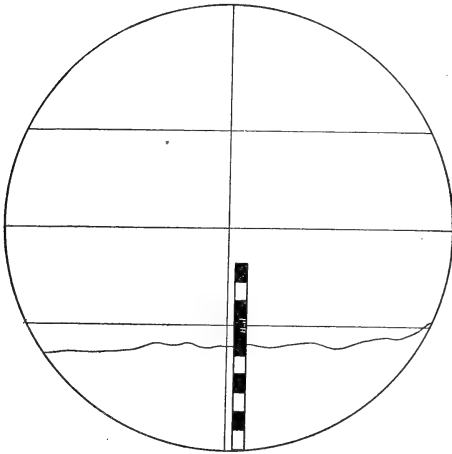


FIG. 8. STADIA ROD IN FIELD OF VIEW WITH LEVEL TELESCOPE AT DISTANCE OF 1050 FEET

The base of the 13 foot rod is 14.8 feet below the elevation of the alidade.

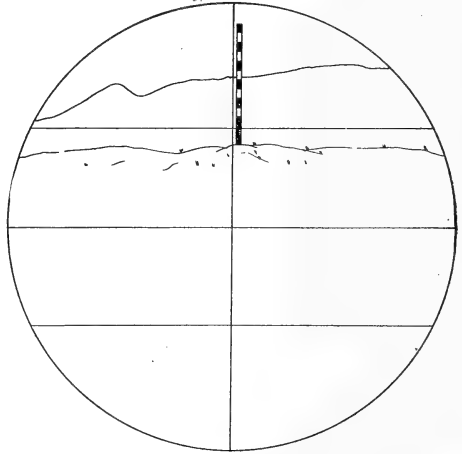


FIG. 9. STADIA ROD IN FIELD OF VIEW WITH LEVEL TELESCOPE AT DISTANCE OF 1960 FEET

The base of the rod is 8.0 feet above the elevation of the alidade.

same object. The bottom hair now appears to be  $1/100$  the horizontal distance, previously determined by the stadia intercept on the rod, below the point where the middle hair had formerly been. If the bottom hair now cuts the rod, read its inter-

<sup>12</sup> Douglas, E. M., The stadia and stadia surveying. Engineering News, vol. 63, pp. 483-484, 1910. Meyer, A. F., The "interval" method of determining elevations in stadia surveys. Engineering News, vol. 64, pp. 231-232, 1910. Edgerton, H. H., Jr., Modern methods of economical railway location. Engineering and Contracting, vol. 41, pp. 229-232, 1914.

section and add that figure to  $1/100$  the horizontal distance to get the V. D. (vertical difference in elevation), which in this case, would be negative. If the bottom hair is still above the rod, note where it in turn intersects some fixed object in the field of vision and turn down the instrument until the top hair occupies its position. The bottom hair now appears to be  $2/100$  the horizontal distance below the point intersected by the middle hair with level sight. The process may be repeated, noting how many "steps" are used, until the bottom hair finally intersects the rod.

Obviously, the same method may be utilized for determining elevations of stations above the instrument by "stepping up" from the level sight until the top hair cuts the rod. Figure 10 illustrates the method. In recording observations it is only necessary to note the observed distance, the number of steps, the final rod intersection, and the sign of the V. D., plus for stations above and minus for stations below the instrument elevation. For example, a sight to a station 1760 feet distant, recorded as "+4 (steps) - 3.5", indicates that the base of the rod is  $(4 \times 17.6) - 3.5$ , or 66.9 feet above the instrument. Or, a sight of 1320 feet with the V. D. recorded "- 3 (steps) - 12.9" indicates that the base of the rod is  $-(3 \times 13.2) - 12.9$ , or - 52.5 feet in relation to the altitude of the telescope.

Attention should be directed again to the fact that the first "step" is in reality only a "half step" for by it one of the outer hairs is moved to the position occupied by the middle hair, whereas, each step, after the first, involves the movement of one outer hair to the position occupied by the other outer hair. This is compensated by the fact that the reading of the rod intersection after the final "step" is a reading of the position of an outer hair, not that of the middle hair. This makes the final "step" really a "step and a half" for the hair, the intersection of which is read, is a half intercept above or below the middle hair.

The "step" method when used by an experienced instrument man is very fast and fairly accurate. It is not, however, sufficiently accurate for important work, as there is wide margin of

error involved in the placing of one hair in the position previously occupied by another. Moreover, there is no simple way of correcting the error resulting from the inclination of sight to the rod when the intercept is read. The "step" method should

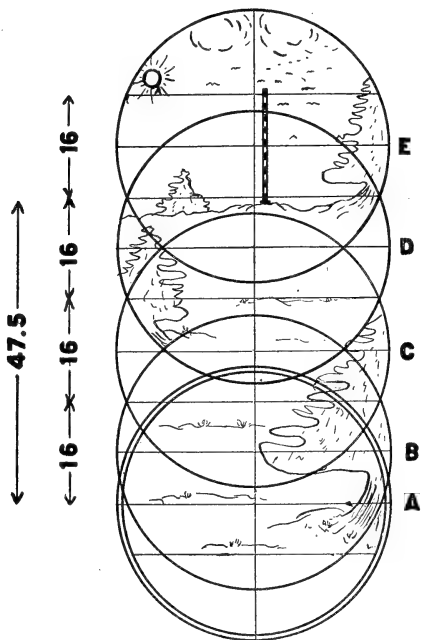


FIG. 10. THE STEP METHOD

Circle A encloses the field of view as observed through the level telescope. Circle B is the field after the telescope has been raised so that the bottom cross hair occupies the position occupied in A by the middle hair. C and D represent the second and third steps, in each of which the bottom cross hair rests in the position previously occupied by the top hair. In D, the third step, the top hair cuts the rod 0.5 feet above its base. The rod intercept, 16 feet, is indicated in E. The base of the rod is therefore  $3 \times 16 - 0.5 = 47.5$  feet above the instrument.

never be used when more than 6 steps are necessary, nor to determine the elevation of a turning-point or set-up. It is well fitted to serve as a check upon the more accurate methods next described, when there is need for especial care to guard against error.

3. *Vertical arc determinations.* Other and more accurate methods of measuring the difference in elevation between two stations depend upon the determination of the vertical angle between the line of sight from one station to the other and the line of sight through the level telescope. The methods differ only in respect to the reading or computation of that angle; all are based upon the same mathematical principle. In figure 7,  $FE$  represents the vertical distance from the intersection of the middle hair on the rod,  $AB$ , to the level of the instrument at  $G$ .  $CD$  is drawn perpendicular to the line of sight,  $GE$ , the angle of inclination of which is represented by  $m$ .

By trigonometry

$$CD = AB \cos m$$

and

$$FE = GE \sin m.$$

But

$$GE = 100 CD = 100 AB \cos m;$$

therefore

$$FE = 100 AB \sin m \cos m = 100 AB \times \frac{1}{2} \sin 2m,$$

the formula upon which stadia tables are based.

The angle of inclination of the line of sight to the target may be read in degrees and minutes by means of the vertical arc. With loosened clamp the telescope is raised or lowered until the middle cross-hair rests *near* the selected target. The clamp is tightened and by means of the tangent screw the middle hair is accurately placed on the target. The point on the vertical arc opposite the zero of the vernier is read to the nearest minute and recorded. The telescope is then leveled, first loosening the clamp if desired, and the bubble in the striding level centered by adjustment of the tangent screw. The point on the vertical arc now opposite the vernier zero is read and recorded; the difference between the two readings is the desired vertical angle.

The graduations of the vertical arc differ on alidades of different manufacture, but one of the common graduations is indicated in figure 11 by the markings on the left half of the arc. The main scale of the arc is divided into degrees and half degrees.

By means of the vernier it may be read in minutes. The vernier is an auxiliary scale on which there are 30 graduations occupying a space equal to that of 29 graduations on the main scale. That is, each division on the vernier is just one-thirtieth smaller than a division on the main scale. If, therefore, the zero line of the vernier is directly opposite a line on the main scale, no other line on the vernier scale will coincide with a division of the main scale except the thirtieth. If, then, the arc be moved one minute ( $=$  one-thirtieth of one division) to the right, the first line on the left of the vernier zero will coincide with a line on the main scale; if the arc be moved 15 minutes to the right, the fifteenth line on the left of the vernier zero will coincide with a line on the main scale, etc. On this principle the arc graduated only to half degrees may be read in minutes. On an arc graduated from right to left, read the highest division to the right of the vernier zero line; this will be either an even degree or a degree plus 30 minutes. Observe which line on the vernier coincides with a line on the main scale; add its value in minutes to the reading of the main scale. For example: the vernier zero is between the  $24^{\circ} 30'$  and  $25^{\circ}$  graduations of the main scale; line 16 on the vernier coincides with a division of the main scale; the arc reading is therefore  $24^{\circ} 46'$ .

A vertical angle of 1 minute subtends a chord of 0.3 feet at a distance of 1000 feet; hence it is imperative that no mistake be made in selecting the vernier division which coincides most closely with a line of the main scale. Most surveyors make it a practice always to use a pocket magnifier in reading the vernier. It is also easier to detect offsets of the main scale and vernier division lines if one looks obliquely along the lines at an angle of 30 or 40 degrees with the face of the scale than it is when observing the vernier face from a direction perpendicular to it. The most common of the serious errors which may involve the vernier reading is to overlook the  $\frac{1}{2}$  degree division of the main scale and count it as an even degree; guard against that blunder by computing the position of the vernier zero twice for each angle.

Most alidades are equipped with adjustable vernier and with main scale so graduated that the vertical arc may be set to read

30° 00' when the telescope is level. Among topographers it is customary, in reading vertical angles, first to level the instrument and set the vernier at 30° 00', and second to turn the telescope down or up for the reading on the distant object. It is then necessary to record only one angle reading—that made after the cross-hair is set on the target; a reading less than 30° 00' indicates an angle of elevation, one greater than 30° 00' an angle of depression if the arc is graduated from right to left. This procedure is not recommended for petroleum geologists, however, because of inherent differences in the work of these two classes of alidade-users. In the topographer's party the lowest-paid man is ordinarily holding the rod on the station to which the sight is being taken. It is of little consequence whether he remains there four minutes or two. When he is moving on to the next station the topographer's time is occupied with sketching contours; he has no idle moments. In the petroleum geologist's party, the reverse is the case. The highest-paid man ordinarily holds the rod; the amount of work the party can do in a day is in inverse ratio to the length of time he is kept idle while the instrument man makes observations. While he is moving on to the next station, the selection of which will ordinarily require 10 to 20 minutes, the instrument man has nothing to do except compute his results—a task which if necessary may be done later in "the office." Moreover, the geologist's plane table is customarily lighter and smaller than that used by the topographer; it is seldom possible to get it in a precisely level attitude. Therefore it would be necessary to level the telescope and set the vernier after the geologist has occupied the fore sight station and while he is waiting for the observations to be made. The procedure of the instrument man should be planned explicitly to minimize the length of time the rodman is kept at a station. Just as much of instrument work as possible should be done after the rodman has been "waved on." With this in mind, the instrument man signals the rodman as soon as the cross hair is set on the selected mark on the rod; after the rodman has departed he reads and records the vernier, levels the telescope, reads and records the new position

of the vernier, wherever it happens to be, and determines the vertical angle by subtraction. He is then under no pressure of haste in reading the vertical arc and in centering the level bubble. To increased speed of geologic work is added thereby greater accuracy in instrumental observations. The record, then, includes two angle readings, one on the target and one with level telescope; the sign of the angle, plus for stations above and minus for those below the altitude of the table; and the observed inter-

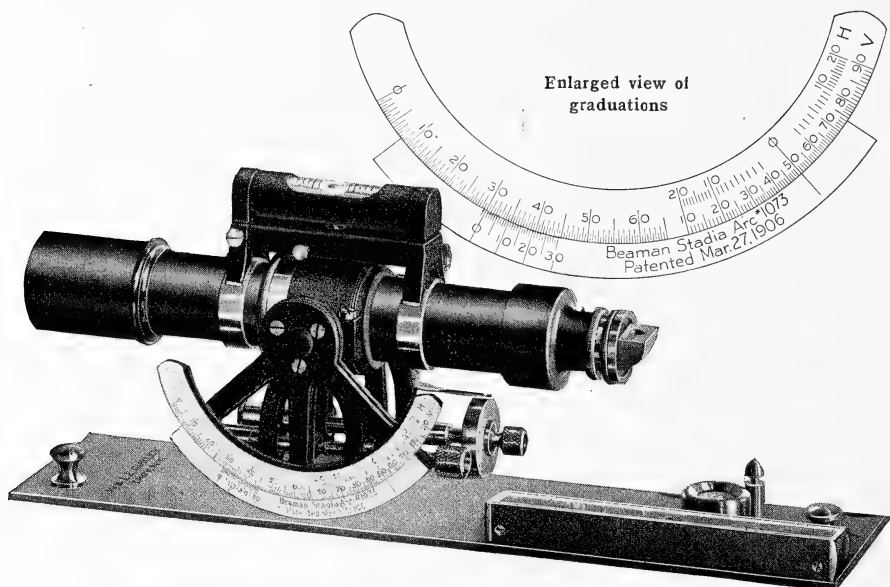


FIG. 11. EXPLORERS' ALIDADE, WITH VERTICAL ARC COMBINED WITH BEAMAN STADIA ARC

Courtesy of W. and L. E. Gurley, Troy, N. Y.

cept on the rod. From these data the vertical distance may be computed at leisure.

4. *Beaman stadia arc.* The reading of vertical angles may be avoided by the use of the Beaman stadia arc, illustrated in figure 11. This is a specially graduated vertical arc which may be attached to the vertical limb of a transit or telescopic alidade. It carries two scales, of which the one nearer the adjustable index is known as the multiple scale because it indicates mul-

tiples for obtaining differences in elevation. The zero point of this scale is marked 50 and its divisions are so spaced as to be proportional to one-half the sine of twice the angle through which the telescope moves.

To determine differences in elevation read the distance subtended on rod and express in feet (for example, 8.7 = 870 feet). Clamp telescope and level. Set index exactly at 50, by means of the tangent screw back of arc, and do not touch this tangent screw again.

Then, by means of the customary clamp and tangent movement, raise or lower telescope until there is brought exactly opposite the index such a graduation on the multiple scale as will throw the middle stadia wire somewhere on the rod, it does not matter where. The arc reading, minus 50, multiplied by the observed stadia distance gives the difference in elevation between the instrument and a known point on the rod—that is, the height on rod indicated by middle wire. Settings of both index and arc should be made carefully under reading glass.

Example: Suppose observed stadia distance is 6.3 (630 feet) and that telescope is so inclined that multiple scale reads 58, at which exact setting the middle wire on rod reads 7.2 (7.2 feet above base of rod) then multiple is  $58 - 50 = + 8$ , and computation for a fore sight would be

$$\begin{array}{r}
 6.3 \\
 \times 8 \\
 \hline
 +50.4 \\
 -7.2 \\
 \hline
 +43.2 \text{ feet} = \text{base of rod above H. I.}
 \end{array}$$

If middle wire were set on H. I. or top or other fixed point on rod and the arc were read by estimation (for example, 54.2) to obtain a multiple, the result would be approximate only; therefore this method is not to be used with this attachment.

If the half-wire interval is read and this reading is then doubled to get the stadia distance, it occasionally happens that no even multiple arc setting which will throw middle wire on rod can be found. In this case make arc setting that will throw the lower wire anywhere on rod; the middle wire will then be somewhere above the top of the rod. Then take multiple as read on arc, but compute position of middle

wire above base of rod by adding one-half the expressed stadia distance (in feet subtended) to the reading of the lower wire.

Example: If the half wires subtend 7.2 on rod, the distance would be  $7.2 \times 2 = 14.4$  (1440 feet). If the lower wire cuts the rod 8.7 feet above its base, the computed middle wire reading would be  $8.7 + 7.2 = 15.9$  feet above base of rod. Then compute as before.<sup>13</sup>

The advantages of the stadia arc are readily apparent. The use of stadia tables, slide rules, or diagrams is entirely obviated, nor is there any vernier to be read. The accuracy of results is identical with that obtained from formula or table computations; in fact differences in elevation may be read more closely than is possible where vertical angles are determined only to the nearest minute. Moreover the simplicity of the process eliminates many of the chances of error which are incidental to the use of other methods and gives final results in minimum time. The use of the arc is, however, limited to sights which involve the reading of the stadia rod, and for most "shots" it holds the rodman on the station longer than is necessary with certain other methods.

If it is desired to use the Beaman stadia arc principle with an instrument not regularly equipped for such work, the ordinary vernier arc may be used by reference to the following table, which is also of use in checking the action of the Beaman scale. It is computed from the formula:—vertical distance =  $\frac{1}{2}$  sine of twice the vertical angle, and gives values by which the Beaman intervals can be translated into angular valuations and vice versa.

5. *Stebinger gradienter drum.* The accuracy of a sensitive bubble vial in the striding level is greater than that implied by the reading of the vertical angle only to even minutes. The fine adjustment tangent screw is so threaded<sup>14</sup> that a complete

<sup>13</sup> Topographic Instructions of the U. S. Geol. Survey, Washington, Gov. Printing Office, 1918, pp. 131-2.

<sup>14</sup> The intention of the makers commonly is to calculate the pitch of the screw and the length of the clamp arm so that one complete revolution of the screw head moves the line of sight 1 foot vertically at a horizontal distance of 100 feet, but this ratio may not be safely depended upon except as a broad approximation.

*Table showing angular values of Beaman intervals\**

NUMBER OF INTERVAL	ANGLE		DIFFERENCE IN MINUTES	NUMBER OF INTERVAL	ANGLE		DIFFERENCE IN MINUTES
	°	'			°	'	
0		00.00					
			34.38				36.16
1	0	34.38		16	9	19.89	
			34.39				36.42
2	1	08.77		17	9	56.31	
			34.42				36.70
3	1	43.19		18	10	33.01	
			34.47				37.00
4	2	17.66		19	11	10.01	
			34.52				37.32
5	2	52.18		20	11	47.33	
			34.59				37.71
6	3	26.76		21	12	25.04	
			34.68				38.08
7	4	01.44		22	13	03.12	
			34.77				38.49
8	4	36.21		23	13	41.61	
			34.88				38.95
9	5	11.09		24	14	20.56	
			35.02				39.44
10	5	46.11		25	15	00.00	
			35.16				39.97
11	6	21.27		26	15	39.97	
			35.33				40.54
12	6	56.60		27	16	20.51	
			35.50				41.16
13	7	32.10		28	17	01.67	
			35.71				41.85
14	8	07.81		29	17	43.52	
			35.92				42.58
15	8	43.73		30	18	26.10	

\*Reproduced by permission from Metro Manual, Bausch and Lomb Optical Co., Rochester, N. Y., 1915, p. 114.

revolution deflects the telescope about 34 minutes, so that if the unit of measurement be  $1/500$  a revolution of that screw, the accuracy of reading vertical angles is greatly increased. This is especially important in determining the difference in elevation of a station two to eight miles distant as is frequently done in triangulation work. The Stebinger gradiometer drum surround-

ing the tangent screw is graduated into 100 divisions, so broadly spaced that the drum may be read accurately by estimation to 0.2 division, and so quickly legible that there is marked saving of time and increased safeguard against error in observation when it is used in preference to the vertical arc. It is in reality simply another method of reading the vertical angle, denoting the angle by an arbitrary unit instead of by degrees and minutes. The value of that unit in length of chord at known distances may be expressed in tables similar to those provided for computation from vertical arc readings.

In most instruments a clock-wise rotation of the Stebinger drum depresses the objective end of the telescope by pressing against a little stud fixed to the inside surface of the right hand standard. A counter-clock-wise rotation permits a spiral spring to expand against the opposite side of the stud and thus to raise the objective end of the telescope. Experience indicates that it is unsafe to trust the spring to act with uniform regularity and smoothness. It is therefore necessary in using the Stebinger method always to read vertical distances in one direction—usually downward<sup>15</sup>—the direction in which the telescope is moved by clock-wise rotation of the drum. If the station is higher than the telescope, the first reading is taken with the horizontal cross-hair cutting the target; the telescope is then turned down to the level position for the second reading. If the station is lower than the instrument, the telescope is leveled for the first reading of the Stebinger drum and then turned down till the cross-hair cuts the target for the second reading.

The fine adjustment screw to which the Stebinger drum is attached is a tangent screw; that is, its motion is tangential to the arc described by the arm of the clamp of the telescope axis. Therefore, a revolution of the screw, when it is near one of its limits of motion will elevate or depress the telescope through an arc slightly different from that resulting from an equal turn of the screw when it is midway between its limits. Therefore it is

<sup>15</sup> In some instruments the screw is fixed to the telescope standard and the stud is attached to the arm of the clamp of the telescope axis; when so attached the direction of movement to be used in reading the gradienter is upward.

necessary always to begin an angle reading with the tangent screw in approximately the same position as that from which the determination of the Stebinger factors was made. This position, generally about a quarter turn of the screw after it first "takes hold," should be indicated by a mark on the celluloid or steel index. After each reading the tangent screw should be withdrawn to that position, ready for the next reading.

In practice, then, the first reading is made with the Stebinger drum somewhere near the predetermined starting point and with the cross-hair on the distant object, if it is higher than the instrument or with the telescope level if the sight is a "down shot." The reading, a figure between 0 and 100, is recorded in the proper column of the note book. The telescope is then turned down by means of the tangent screw to position for the second reading. As the Stebinger drum revolves the total number of revolutions should be counted. The count may be verified by the graduations on the index bar if present and is set down at the left of the two digits which indicate the Stebinger division beneath the index. For instance, after completing 8 revolutions, the Stebinger drum is brought to rest at 67; the second reading is therefore recorded in the appropriate column as 867. With an alidade which "reads down," as is the more common arrangement, the smaller of the two Stebinger readings will be in the "Sight" column if the target is higher than the instrument, and in the "Level" column if lower than the instrument. The difference of the two readings expresses the size of the vertical angle in terms of Stebinger divisions. From the Stebinger tables prepared for the individual instrument the corresponding "Stebinger factor" is selected. This factor multiplied by the apparent distance gives the difference of elevation of target and plane table.

The preparation of the Stebinger tables is essentially the determination of the value of Stebinger units in terms of circular measure. Withdraw the micrometer screw to the position from which determinations of vertical angles will be started. Set the drum on an even division and read the vertical arc; turn the drum through 100 divisions and read the arc again. Turn

through 200, 300, etc., divisions, reading the arc at each hundred until the screw has reached the farther limit of its play. Usually 9 or 10 hundred divisions will suffice. Repeat the operation at least five times and take the average value in minutes for each hundred divisions. Determine the corresponding difference in elevation for each of these angles by interpolation of the regular stadia tables or from a table of natural sines by the formula: Difference of elevation =  $\frac{1}{2}$  sine of twice the angle. The first value thus determined divided by 100 is the difference in elevation corresponding to each Stebinger division between 0 and 100. The second value minus the first and divided by 100 is the difference in elevation corresponding to each Stebinger division between 100 and 200. The third minus the second and divided by 100 is the value for Stebinger divisions between 200 and 300, etc. Carry the quotients in each case to the fifth decimal. With an adding machine set at the difference in elevation for one division between 0 and 100, print 100 additions for the factors corresponding to the first 100 Stebinger divisions. Then with the machine set at the difference in elevation per division between 100 and 200, print 100 additions for the factors corresponding to the second 100 Stebinger divisions. Complete the table in this manner, changing the addition figure after each 100 additions. Number the divisions, strike out the extra decimals beyond the third for the first 50 divisions and beyond the second thereafter, and typewrite into tabular form in parallel columns; the number of divisions in one column, the corresponding factors in another. Brief tables for correction because of curvature and refraction as well as for conversion of observed to horizontal distances should be added at the margin. The whole, if properly planned, will occupy a sheet about  $5 \times 7$  inches in size when photographed to one-half reduction for field use.

A slight modification<sup>16</sup> of the above method will give a still more accurate series of factors. Read the vertical arc at each 50th division of the Stebinger drum instead of each 100th; deter-

<sup>16</sup> Suggested by K. C. Heald of the U. S. Geological Survey.

mine the corresponding difference in elevation for each Stebinger unit as before; with the factors thus obtained plot a curve using the numbers of divisions as the abscissas and the values as the ordinates. From this curve the point will be readily apparent at which the micrometer screw begins to work with reasonable uniformity; begin constructing the table to be used at that point. From the curve determine the points where the factors for two successive divisions differ by 0.00005 and compute the factors for the number of divisions represented by each of these points; interpolate between the values thus obtained to complete the table.

The table of Stebinger factors should be checked every few weeks by comparing a half dozen Stebinger readings, made at haphazard intervals well distributed throughout the range of the micrometer screw, with the corresponding readings of the vertical arc. The Stebinger factor should be identical, on the average, with the vertical distance corresponding to the arc reading.

In reading the Stebinger drum the observation should be made from directly above the celluloid or steel index so as to project the index line vertically downward to the drum. Ordinarily, a reading to the nearest Stebinger division is sufficiently close, but for low angles and long "shots" it is better to estimate half divisions, and for the nearly horizontal two-to-five mile "shots" of triangulation it is frequently worth while to estimate to tenths of a division. For these long sights, the distance of which is determined by scaling off the space on the map, there is a theoretical error in using tables based on the formula involving one-half the sine of twice the angle, but there is practically no discrepancy here for the difference between the sine of a small angle and one half the sine of twice the angle is negligible.

#### CURVATURE AND REFRACTION.

No matter what method of determining vertical distances is used, a correction for curvature and refraction must be applied to all "shots" of a mile or more in length. The level datum to

which all elevations are referred is a surface having the curvature of the Earth; the line of sight through the telescope in a level position is tangential to this curved surface; therefore distant objects appear to be higher above the datum plane than is actually the case. In the greatly exaggerated figure 12, for example, the rod reading is increased from *C* to *A*. The result of curvature can be determined with reasonable accuracy. It varies directly as the square of the distance and may be computed by the formula:  $\text{Curvature} = 0.667 \times D^2$ , where *D* is the distance in miles.

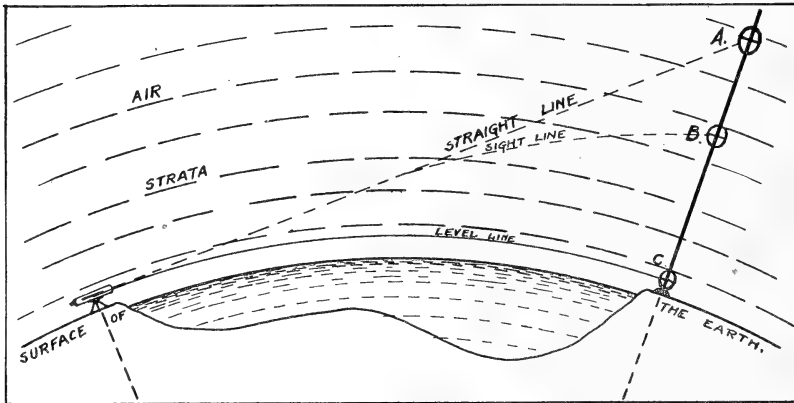


FIG. 12. DIAGRAM, GREATLY EXAGGERATED

Showing influence of curvature and refraction upon observations for determining differences in elevation between two points.

Refraction, on the other hand, has the opposite effect. When light rays pass obliquely from one air stratum to another of different density they are bent or refracted from their original position. In figure 12, the light from the target at *B*, passing into air strata of increasing density as it travels to the alidade at the left, is bent downward and enters the telescope as though it had come by a straight line from *A*. Thus, the effect of normal atmospheric refraction is to make distant objects appear higher than they really are. It, therefore, tends to decrease the curvature correction, as shown in the figure. The amount of refraction depends upon the density of the air and is, therefore, quite

variable. It is much greater near the ground than 3 feet above it, and generally greater at midday than early in the morning or late in the afternoon.<sup>17</sup> The empirical valuation ordinarily placed upon the effects of refraction gives the combined formula: Curvature plus refraction =  $0.57135 \times D^2$ .

A table showing corrections based on this formula may be found in the ordinary stadia tables. The correction amounts to only 0.1 foot for distances of 2200 feet, 0.2 foot for 3125 feet and 0.5 foot for 4940 but increases rapidly to more than 5 feet at 3 miles and 20 feet at 6 miles. It may safely be disregarded for the great majority of rod "shots," which will of course be less than 3000 feet long.

The correction is always a minus quantity and should be added algebraically after the proper sign has been placed in front of the vertical distance as instrumentally determined. It will thus increase the vertical distance for angles of depression and decrease it for angles of elevation on all fore-sights. Occasionally, for nearly level sights the correction to be applied for curvature and refraction will be greater than the observed difference in elevation, and the sign of the vertical distance may than be changed. No confusion will arise, if the rule stated in the first sentence of this paragraph be rigidly observed.

#### ADJUSTMENT OF THE ALIDADE

The most important adjustments of the miniature or explorer's alidade, which require attention in the field, are those for collimation and of the striding level. All other adjustments are reasonably permanent as made in the factory. It is, however, well for the instrument man to be able to detect, and if possible correct, faulty workmanship or damage from mistreatment or accident.

*Collimation.* The line of sight through the telescope is determined by the intersection of the cross-hairs, whatever their position in the tube, and the nodal point in the objective lens.

<sup>17</sup> Obviously, the refraction to which reference is here made is not that of the direct rays of light from sun or stars. The refraction for which correction must be made in determining sun azimuth is least between 9 a.m. and 3 p.m.

This line is correctly collimated when it coincides with the optical axis of the objective. That is, the intersection of the cross-hairs should remain stationary in the field of vision when the telescope is rotated on its horizontal axis. The telescope is mounted between 180-degree stops in the axis-sleeve for this purpose.

Sight some distant fixed object of small size and center the cross-hair exactly upon it. The telescope need not be horizontal. Rotate the tube carefully half way round and twist the prismatic eye-piece back into position. Note whether the cross-hairs are still centered upon the object. If not, correct half the

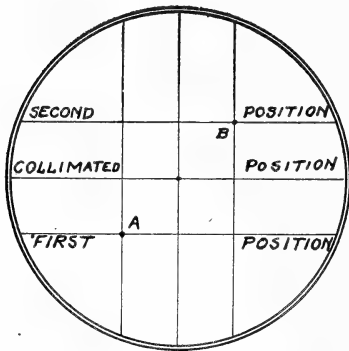


FIG. 13. DIAGRAM ILLUSTRATING  
THE ADJUSTMENT FOR  
COLLIMATION

discrepancy by means of the diaphragm adjusting studs, which may or may not be concealed beneath a ferrule which forms a guard against accident or tampering. In figure 13, let the original position of the cross-hairs be represented by the lines passing through the point *A*, their position after rotation of the telescope by the lines passing through the point *B* and their collimated position by the lines passing through the center of the circle. Move the vertical hair to left or right by turn-

ing both lateral studs in the same direction, first slightly loosening the one, then tightening the other. If the alidade is of the erecting type with field reversed from right to left, as is commonly the case, loosen the screw *away from which* the vertical hair must apparently be moved, and tighten the opposite screw. Move the horizontal hair up or down by turning top and bottom studs in the same direction, first slightly loosening the one and then tightening the other. If the eyepiece is of the erecting type, loosen the screw *towards which* the horizontal cross-hairs must apparently be moved and tighten the opposite screw. Having corrected half the discrepancy in this way, shift the alidade until the cross-hairs are again centered upon the distant object, and

rotate the telescope as before. The line of sight should now remain fixed upon the distant point; if it does not do so, correct half the apparent error as before. Repeat until the hairs are properly centered.

The test for collimation should be frequently made. No important triangulations should be begun until one is certain that the cross-hairs are properly located. Should the instrument be subjected to any unusual jar, it must be collimated before it is again used. In the normal routine of field work the position of the cross-hairs should be examined at least once each week.

*Striding level.* The line of sight when correctly collimated should be in absolute parallelism to the bubble axis, which is a line tangential to the curved surface of the striding level vial at the center of its scale. The two "red metal" collars which support the striding level are trued in the factory to the axis of rotation defined by the axis-sleeve within which the telescope rotates. There is very little chance for wear in the sleeve and the collars themselves are subject to little or no wear, so that this adjustment is a fairly permanent one. The customary test of parallelism is therefore simple and rapid. Level the telescope by the striding level, then turn the level end for end on the collars. If the bubble does not come to rest in the same position as before, correct one half of the indicated error with the tangent screw and the other half in the striding level by turning the set screw in the crotch of one of the wyes with a screw driver. This will secure parallelism between the bubble axis and the contact points on the collars, but does not guarantee parallelism with the line of sight although that has supposedly been provided for by the maker of the instrument. The reliable test is that of the peg-method described in most surveying manuals.<sup>18</sup>

*Stadia constant.* In alidades of the type customarily used by geologists, the distance between the stadia hairs is fixed in manufacture and may not be adjusted in the field. Occasional test should be made to ensure a close approximation to the fixed

<sup>18</sup> Tracy, Plane Surveying. New York, 1907, pp. 597-600. Metro Manual, Bausch and Lomb Optical Company, Rochester, N. Y., 1915, pp. 19-20.

ratio of 1:100 between observed intercept on the rod and distance from alidade to rod. Read the rod intercept at accurately measured distances between 100 and 1000 feet from the instrument. If the stadia hairs do not give intercepts sufficiently accurate for the work in hand, the discrepancy may be remedied either by preparing a specially graduated rod adapted for the particular alidade or by computing a constant by which observed distances must be multiplied in order to give true distances.

*Bullseye level.* The inner surface of the circular bubble by means of which the alidade base is made approximately to coincide with the horizon is that of a sphere of long radius. The alidade base should be parallel to a plane which is tangential to this sphere at the point defined by the bubble indices. Once adjusted in the factory it is rarely necessary to rectify the bubble to keep this parallelism within the rather broad limits required for plane table work, but in case of this necessity place the alidade upon a plane surface which is known to be level in all directions and tighten the screw toward which the bubble seems to creep.

*Telescope axis.* In order that the vertical cross-hair shall travel in a vertical plane, the telescope axis must be adjusted to horizontality. The requirements for plane table work are sufficiently met by the plumb line test. Carefully level the plane table and place the alidade along a ruled mark. Hang a plumb line in the field of view and revolve the table to check against it. If the vertical hair deviates to the right for instance, reverse the alidade along the guide line and test on another plumb line swung in the new field of view. If in this case the vertical hair deviates an equal amount to the left, the test will show that while the plane table is not horizontal in the direction of the telescope axis, the axis itself is correct.

Adjustment of the horizontal axis, should this ever become necessary, cannot be made in the field. The factory adjustment is considered to be so permanent that an adjusting block is not provided on alidades. Moreover, it would be difficult to fit such a contrivance, for the vertical arc is on one extension of the horizontal axis and the vertical clamp is on the other.

*Fiducial edge.* While it is not essential for the fiducial edge to be more than approximately parallel with the line of sight, it is important that this edge be straight. Draw a line against the straight edge and turn the alidade end for end. If the straight edge coincides perfectly with the test line, the requirements are satisfied.

#### CARE OF THE ALIDADE

Like all instruments of precision the alidade must be handled with extreme care. Its metal parts are composed almost exclusively of brass, bronze, and "red metal," materials which are not notably resistant to abrasion. Precautions should constantly be taken, therefore, to keep the bearings free from gritty particles. The instrument, for example, should never be placed on the ground or laid on a rock pile. If for any reason it must be removed from the plane table, return it to its leather case and close the case tightly before depositing it anywhere. The bottom must be kept clean. The instrument in its case should at all times be protected against jar and shock. The habit of dropping the alidade to the floor of an automobile to be shaken around in transit with hammers, specimens, tire tools and other impedimenta is indefensible. Treat it with at least as much consideration as one gives to lunch-kit and thermos bottles.

Once or twice a month, bearings, clamps and screws should be wiped clean with a cloth dampened in a light oil such as "3-in-1." The springs which play against the bearing studs on the opposite sides from the vernier and tangent screws should be removed from their housings, wiped clean, stretched a little and replaced.

If the Stebinger drum is used in determining the elevations, the tangent screw must be treated with special care. Experience indicates that very trivial and unobtrusive things may change the relation of the screw to the arc sufficiently to make a Stebinger table no longer applicable and necessitate the construction of a new one. If possible, the grader screw should be entirely withdrawn every week or two and wiped absolutely clean with the oily cloth. The bearing plate stud against which the point

of the micrometer screw pushes must be kept securely tightened. Should it become loose very erratic readings will result. The surface of this plate will gradually wear at the point where the micrometer screw bears against it until a distinct socket is made. Ultimately this becomes so pronounced that not only does it throw out the relation of the straight line push of the screw to the circular movement of the arc, but the point of the screw will not hit exactly the same spot on successive readings, and as a result three or four readings from the same station to the same object will fail to check. When that happens, the bearing plate should be surfaced with a file and a new gradienter table constructed.

The compass needle should always be raised from its pivot and clamped immediately after it has been used. "Protect the pivot in every way possible, for unless the pivot is sharp and perfect the needle may be sluggish and unreliable." Place the alidade as nearly as possible in the magnetic meridian before releasing the needle, and thus avoid the blow to the needle resulting from sudden contact with the compass box. The danger of destroying the polarity of the needle is another reason for guarding against reckless treatment of the alidade as a whole. When working in the rain, the compass box is the most vulnerable part of the instrument. Unless the glass cover is securely sealed all around, moisture will penetrate the box and put the needle out of commission by causing it to adhere to the inside of the glass. If this occurs, the box must be opened, the needle removed, and all parts thoroughly dried before proceeding with the work.

## THE IMPORTANCE OF DRAINAGE AREA IN ESTIMATING THE POSSIBILITIES OF PETROLEUM PRODUCTION FROM AN ANTICLINAL STRUCTURE

KIRTLEY F. MATHER AND MAURICE G. MEHL

So fully is the general dependence of commercial accumulations of petroleum on rock structure accepted among the oil fraternity that the average report setting forth the possibilities of oil and gas production properly centers about the structure of the region concerned. Experience has indicated that accumulations of petroleum usually coincide with certain variations in the attitude of the reservoir rocks; mobility of liquid and gaseous hydrocarbons in tilted porous beds has been recognized to the extent that these structures are looked upon as entrapping "basins" or checks to the upward movement of hydrocarbons along the inclined strata. Attention, however, is usually focused on the nature of the accumulating structure or trap rather than on the nature of the area from which petroleum or gas could have been gathered. In the more common descriptions of a favorable structure, concise statements are made concerning its effectiveness as a trap as indicated by the amount of closure and the size of the area beneath which accumulations of oil or gas should occur; too often nothing is stated concerning the possible feeding ground which may have served as the source from which the oil or gas must come. Account is seldom taken of the fact that a large and effective accumulating structure may be so situated that it could have drawn an accumulation of petroleum from only a very small area; or, as we are here using the term, that the "drainage area" may be of such slight extent as to be insufficient to supply all the oil or gas which could be retained in the structural trap.

A map showing geologic structure by means of contour lines should therefore convey two items of valuable information to the

man interested in the oil and gas resources of the region represented: (1) the location and extent of the areas beneath which oil and gas migrating up the dip of the reservoir rocks would be trapped; (2) the size of the area from which the mobile hydrocarbons might be expected to move toward this trap. The first of these is important in determining the location of drill holes; the second is an equally important factor in determining the volume of possible production from the favorable structure.

To those uninitiated into the mysteries of contour lines—and many such must constantly be dealt with in the petroleum industry—neither of these facts is apparent from the ordinary structure contour map. If the structure of the region be at all complicated, even the connoisseur must spend much time in a careful analysis of the contour lines before he can visualize the structure in all its details and grasp adequately the information thereby set forth. It has been found helpful in the interpretation of structure contours to draft an auxiliary map so planned as immediately to focus the attention upon these two facts undistracted by a maze of lines.

To illustrate the method and the result, there is presented herewith a structure contour map (plate XIX) of the four townships in the southwestern corner of the Pawhuska Quadrangle, Osage County, Oklahoma. The contour lines, redrawn from the township plats prepared by Heald, Winchester, Bowen, Condit, Emery, Clark and Mather,<sup>1</sup> represent a region of complicated structure comprising 31 anticlines and domes of sufficient individuality to be given distinctive names. Accompanying this contour map is an oversheet reproduced from a map prepared by N. L. Thomas, a member of our class in petroleum geology, delineating the area of each inverted basin and drainage tract. The space embraced within the lowest closed contour line on each anticlinal fold is diagonally ruled; the direction of migration of oil or gas in the reservoir rock is indicated by arrows; the feeding ground from which the hydrocarbons, accumulated on or

<sup>1</sup> Structure and oil and gas resources of the Osage Reservation, Oklahoma, Twps. 24 and 25 N., Rs. 8 and 9 E., U. S. Geol. Survey, Bull. 686, parts E, M and P, 1918-1919.

near the crest of each fold, may have been drawn is enclosed by a sinuous line.

A merely desultory glance at the oversheet is sufficient to enable one to grasp the import of the structure of the region so far as its influence upon the accumulation of oil and gas is concerned. If we assume that a suitably porous reservoir stratum is continuous beneath the surface of the entire region, that hydrocarbons were at one time disseminated uniformly throughout that stratum, and that they have subsequently moved up the dip in obedience to gravitational sorting, we may conclude that oil and gas will be concentrated in and near the shaded tracts in amounts proportional to the size of the feeding grounds or drainage areas.

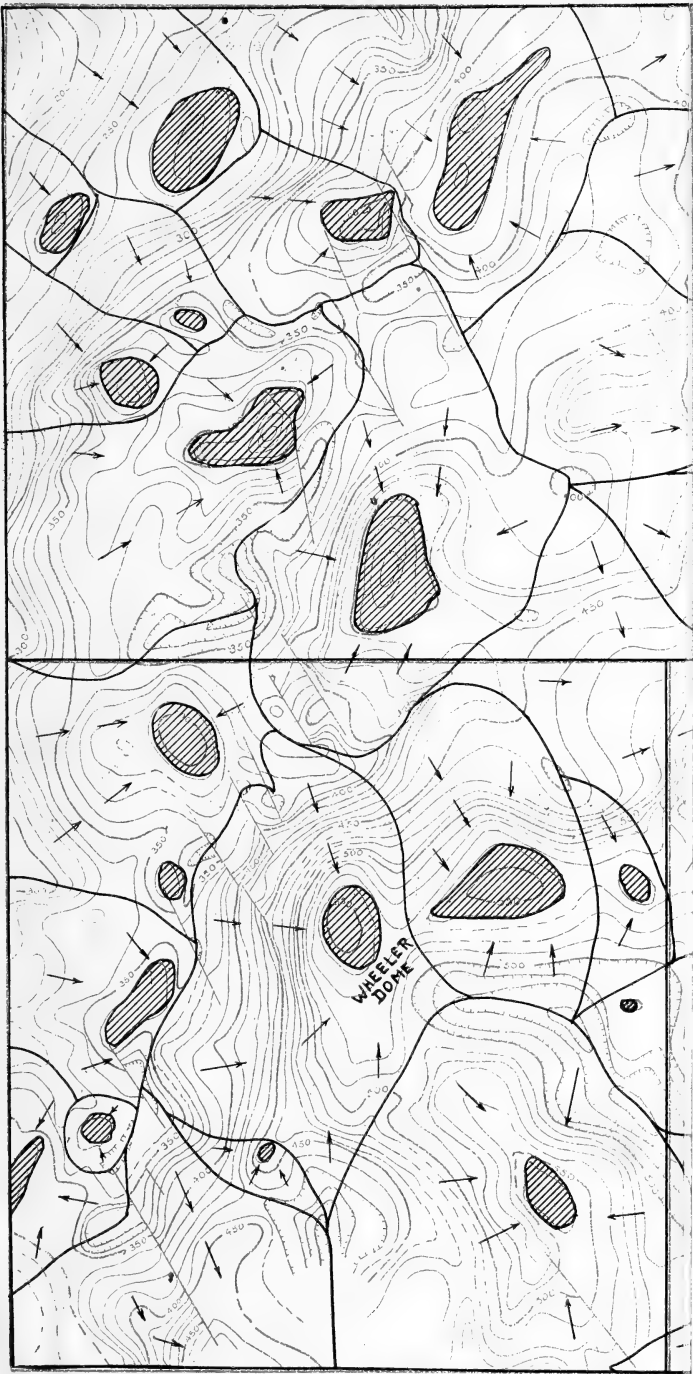
Such a map obviously fails to present a complete picture of the geologic structure of the region. Where the rocks are faulted, as they are in the area chosen for illustrative purposes, the structural drainage areas may be outlined only after making certain unsupported assumptions as to the effect of faults upon the movement of the hydrocarbons. Here, for example, it was assumed that faults whose maximum throw at the earth's surface was less than 30 feet would not have prevented the up-dip migration of oil or gas, while a fault with a throw of 50 to 70 feet—such as the one which slices the Ducotey anticline in 15-25-9—is believed to have effectually halted such migration. Again, change of dip angle without any actual reversal of dip direction or closure of contour lines may be all that is needed to trap the migrant hydrocarbons; but it is impossible to state in advance how much flattening of the beds is necessary to permit a structural terrace to localize an oil or gas accumulation. In the illustrative case, it was decided to neglect all changes of dip angle and consider as traps only true domes or doubly plunging anticlines. The drainage outline map must therefore be used only in connection with the contour map on which it is based; it is to serve as an aid to the ready interpretation of the structure contours, not as an independent entity.

Possibly the greatest value of such a map to the petroleum geologist is that it brings into merited prominence the factor of

drainage area. In our illustration, for example, the Wheeler dome near the center of 24-8 has about the same area within the lowest closed contour line as has the northeastern bump on the Wooster anticline in 27-25-9; the latter has 50 feet of closure, the former only 30, and hence the latter would be considered by many as a more valuable structure; but the oversheet draws attention to the fact that the drainage area contributory to the Wheeler dome is more than twice that which may have fed this portion of the Wooster anticline, and hence, other things being equal, the Wheeler dome should contain more than twice as much oil.

Outlining the possible gathering ground for each anticlinal fold, as on the accompanying plate, serves also to depict clearly certain of the peculiarities of distribution of producing wells in the Osage Reservation. In general, it is noted that the folds are so closely crowded that the drainage areas are all very small. In certain parts of the Reservation good production is obtained from pools so situated that none of the oil which they contain could have come from a greater distance than  $1\frac{1}{2}$  miles. On the average, oil beneath Osage County has probably migrated only 2 or 3 miles from its point of entrance into the reservoir stratum to its resting place in an oil pool. Few accumulations are so situated as to have drawn oil or gas from points more remote than 4 miles.

Again, the asymmetrical situation of the effective trap, almost invariably much nearer the eastern than the western margin of the drainage area, is forcibly presented. Experience indicates that production extends much farther down the longer flanks of the anticlinal folds than the shorter. Where the east flank is less than a mile long, little oil is found east of the crest of the fold; the area from which that portion of the anticline may have been supplied was insufficient to permit a commercial accumulation. In general, the amount of production from the various parts of an anticlinal fold seems to depend largely upon the length of the slope from the margin of the drainage area.

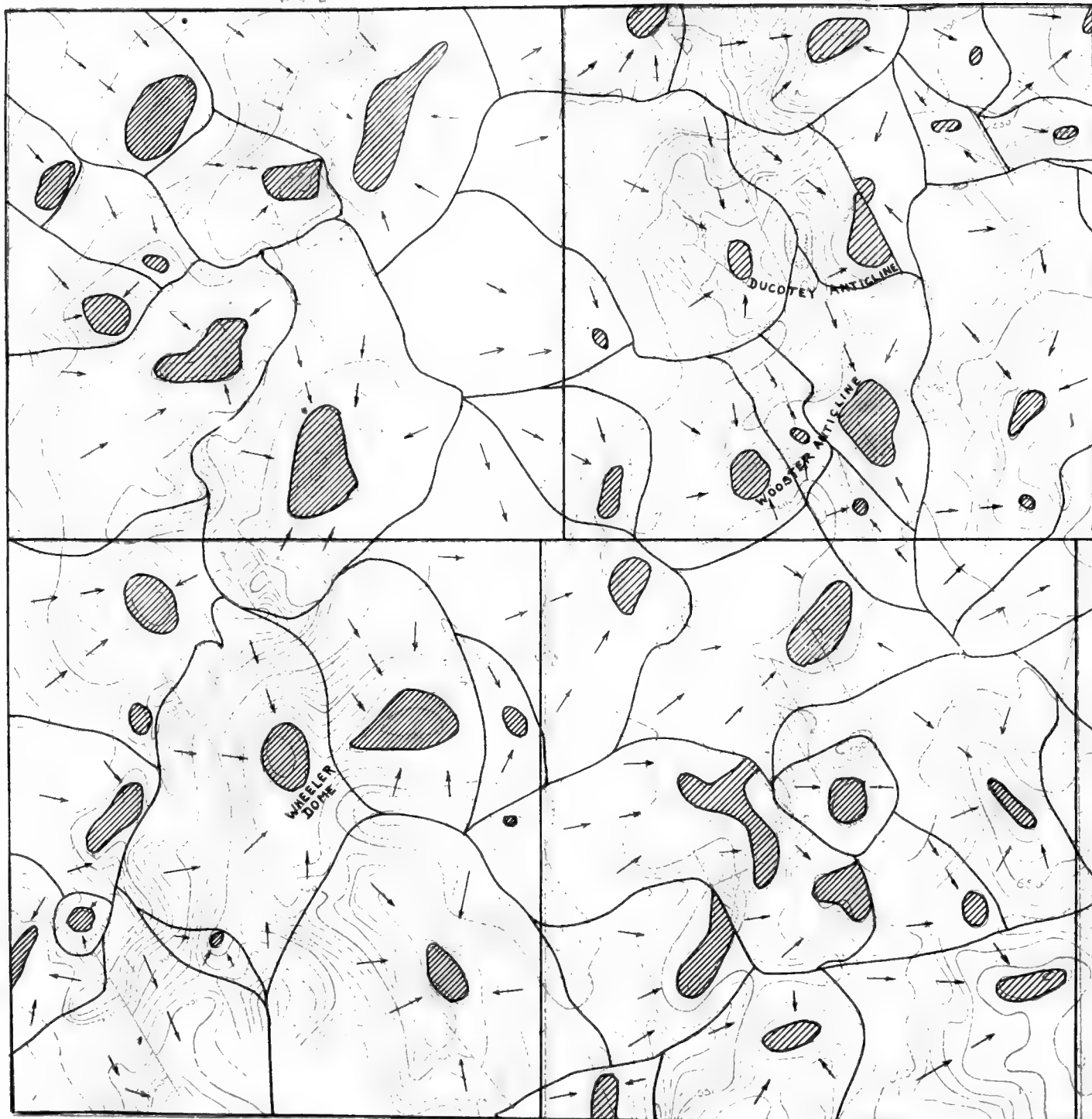


Map showing structural drainage areas in southwestern Iowa for inverted traps for oil and gas within closed contours, a



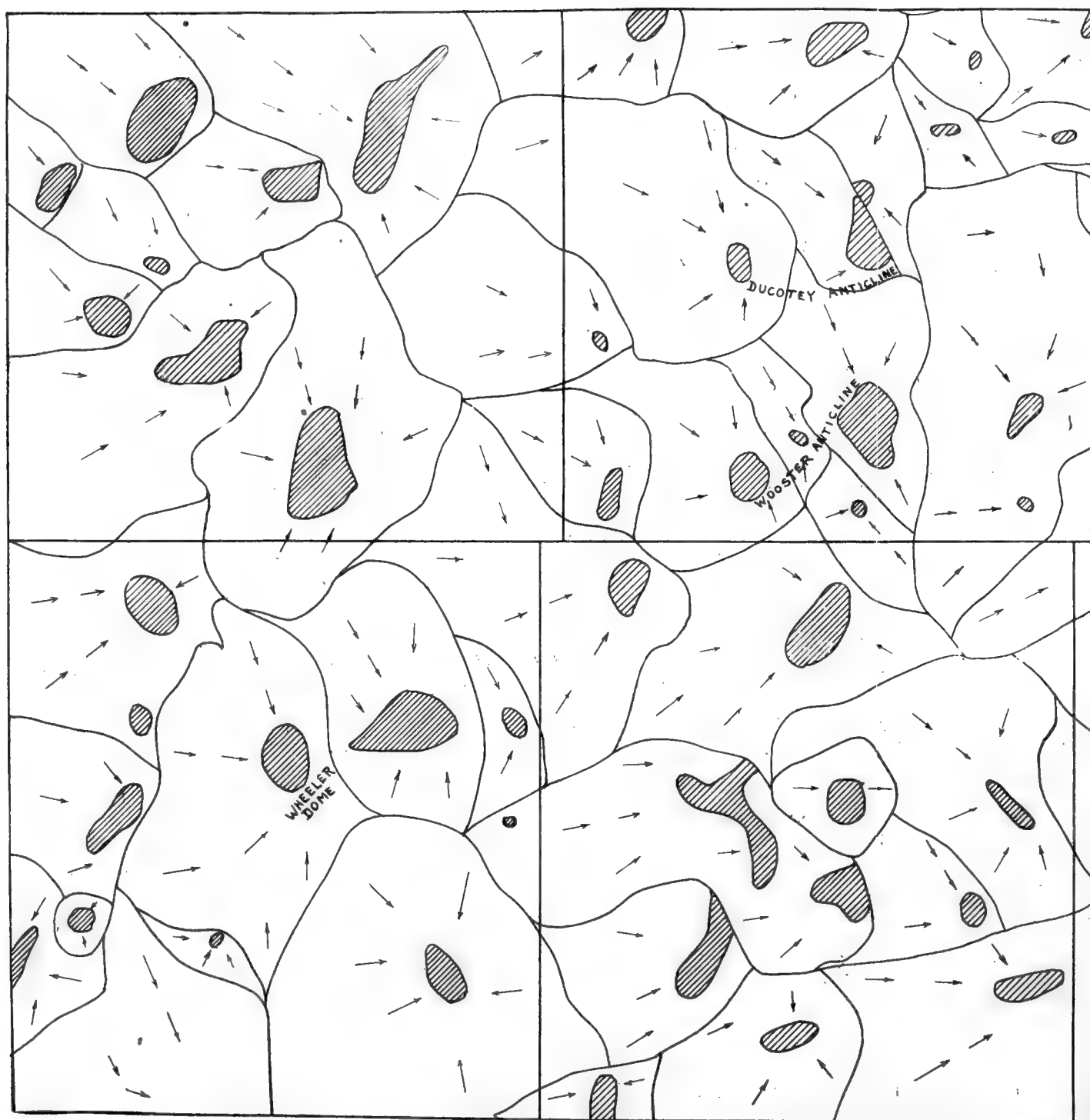
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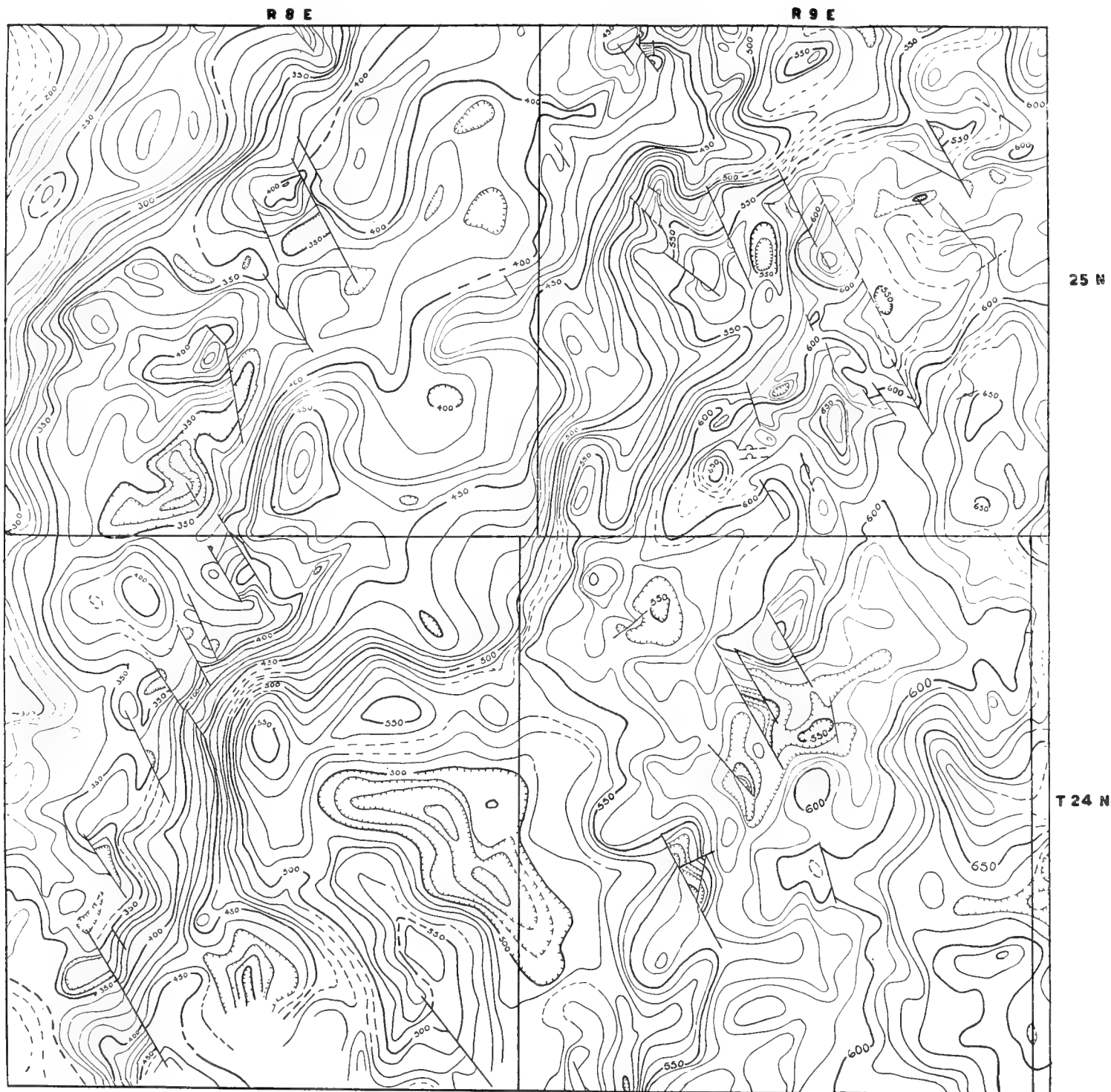
Map showing structural drainage areas in southwestern portion of Pawhuska quadrangle, Oklahoma. Shaded areas are inverted traps for oil and gas within closed contours; arrows indicate direction of migration of oil and gas.





Map showing structural drainage areas in southwestern portion of Pawhuska quadrangle, Oklahoma. Shaded areas are inverted traps for oil and gas within closed contours; arrows indicate direction of migration of oil and gas





Map showing geologic structure of southwestern portion of Pawhuska quadrangle, Oklahoma. Contour interval, 10 feet; scale, 1:114,500. Redrawn from Plates VII, XXIV, XXV, and XXXII, Bull. 686, U. S. Geol. Survey, 1918-1919



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## PSYCHOLOGICAL FACTORS IN VOCATIONAL GUIDANCE<sup>1</sup>

THOMAS A. LEWIS

Vocational guidance is a short name for "the conservation of the energies and talents of human workers." The object is to secure for the new generation, by expert assistance, that occupational adjustment which reduces waste and worry to a minimum. It is an attempt to afford boys and girls and young people the aid so much needed by them in order that they may choose the vocations in which they will have the best chance for personal success and for public usefulness. Putting the matter concretely, it is an attempt to prevent such situations as that typified by the firm which utilizes the services of a thousand salesmen, but "to keep the ranks of that thousand full hires from five to seven thousand men a year."

The main field for vocational guidance is in schools and colleges, because by centering the undertaking there practically every person who has yet to choose a vocation may be reached and that at an opportune time. With guidance machinery installed in the later elementary grades the 40 per cent that drops out as soon as the law allows will not fail to receive its benefits, and with this machinery still operating in the college those who make their decisions at this relatively late age will not be neglected. Vocational guidance in connection with manual vocations extends out into the occupation in the case of those pupils who enter the busy world early and need "follow-up" supervision to keep them from getting trapped in "blind-alley" jobs; and in the case of students in educational institutions where the "part-time" plan is in operation, and where the student divides his time between school and work. In this latter

<sup>1</sup> Address of the retiring President at the regular semi-monthly meeting of the Denison Scientific Association, October 7, 1919.

instance guidance takes its cue as much from the way the individual gets along "on the job" as from the run of things in his study-life. There is an extreme swing of vocational guidance to the occupational end in the case where the psychological expert stands at the door of the business concern and by use of various kinds of tests attempts to find the right men for the different places, shutting out the others.

There is more to vocational guidance, of course, than just what is being done by the psychologist in his diagnostic testing. In the opinion of the Commission on the Reorganization of Secondary Education, "vocational guidance should be a continuous process designed to help the individual to choose, to plan his preparation for, to enter upon, and to make progress in an occupation." That this task is many-sided and therefore calls for the coöperation of many minds is indicated by the nature of the program set by the committee for carrying it through. The program consists of eight steps, as follows:

1. Survey of the world's work.
2. Studying and testing pupils' possibilities.
3. Guidance in choice and rechoice of vocation.
4. Guidance with reference to preparation for vocation.
5. Guidance in entering upon work; that is, "placement."
6. Guidance in employment; that is, "employment supervision."
7. Progressive modification of school practices.
8. Progressive modification of economic conditions.

The outline, it will be seen, assigns sufficient work for teacher, school administrator, vocational counsellor, parent, psychologist, and others. It is only to be noted that the psychologist is assigned a particular part, namely, "studying and testing pupils' possibilities." Not that he alone is assigned this topic, though there is evidence that his services here are going to increase in volume and reliability.

The late Prof. Hugo Muensterberg, of Harvard University, was very optimistic about the future of vocational psychology. He thought that the problem of vocational guidance "had

already been handed over from the vocational counsellors to the experimental psychologists." In his mind, "the laboratory method" was as superior to the "mere-impression" method as "the microscope is superior to the human eye." As a rule the investigators in this line are more moderate in their claims and expectations, and for the two reasons, namely that (1) the technique of mental measurement is not so highly perfected as the microscope and (2) the material to be dealt with is of the most complex kind.

The committee on vocational guidance appointed by the National Education Association makes a three-fold classification of the experimental work being carried on by the vocational psychologist, namely:

(1) The attempt to supply the employer with tests that will enable him to select from a large number of applicants those most likely to succeed in a given position (vocational selection); (2) the attempt to determine specific vocational abilities—that is, which of several occupations would be the best one for a given individual to follow; (3) the attempt to develop tests for the measurement of general intelligence.

Professor Muensterberg, who was one of the first men in this country to go at the matter of vocational guidance laboratory fashion, performed experiments to weed out applicants and also to discover personal aptitude. His tests (which were not of the general intelligence variety, but were tests of reaction time, association, attention, etc.) were applied, as he said, from the side of "the scientific manager who seeks the best man for the work; and from the side of the vocational counsellor who seeks the best work for the man." He thought that by so doing the interests of both sides were provided for. Being a pioneer in this new world of discovery, Muensterberg did not blaze the way very far, but what he did was of practical value and rather significant. His investigations were concerned with finding out what sort of equipment was required of a person who could be counted on to succeed as a typesetter, a motorman, a telephone operator, etc. His methods and results in the case of the motorman are typical. Assuming that for motormen on street rail-

ways "the essential ability consists in the power to combine continuous attention with an impulse to quick reaction, and with a certain imagination by which the movements of pedestrians and vehicles are foreseen," he contrived a device whereby it was possible to test a man for these specific characteristics. There was a crank which the subject turned, and red and black puppet figures that appeared on a passing screen in different combinations, and the noting of certain particular combinations seemed to be the thing that told the tale. The number of the mistakes made in this particular and the rapidity in turning the crank were measured. "Experienced motormen felt, in carrying out this experiment," says Muensterberg, "that the mental attitude was indeed quite similar to that of their function on the street." He remarks upon the fact that "13 per cent of the gross receipts of some roads go for damages due to avoidable accidents," and significantly adds that his "experiments resulted in the rejection of one-fourth of the applicants for positions as motormen."

Other men engaged in psychological research have also become greatly interested in recent years in the practical possibilities of the science, and in some institutions of higher education (Carnegie Institute of Technology, for example) applied psychology has assumed large proportions.

But it is the service performed in connection with the organization of our recent Army that vocational psychology stands out. Psychology here undertook a task of mental engineering which was on a scale so vast as to require of the specialists in that field the abandonment for the duration of the war of many or all of their other duties. The classification of the membership of the Army on the basis of trade abilities and general intelligence and officer qualities was largely the psychologist's responsibility. The dual problem (set by Muensterberg) of studying the man and the occupation as the prime fundamental in vocational guidance, was attacked in great earnestness, and with the result that it became possible to select officers with some assurance that right selections were being made, to classify recruits according to their capacities both to learn what a soldier must

know and to do what a soldier must do, and "to locate every man that had any kind of special skill that the Army might need." The methods followed in working up these different tests, as well as the results obtained by their use, are significant as indicating the way the thing must be done if any contribution to vocational guidance is to be made from this source. In formulating the trade tests, to use this set of tests as an example,

The committee sought material from all promising sources. These included skilled mechanics in all the trades represented, trade-union officials, employment managers, factory superintendents and foremen, the United States Bureau of Labor Statistics, civil service examiners, and Army officers in all branches of the service.

A first-hand study was made of the mechanic on his job. With the assistance of skilled workers in each trade, the essential elements of the processes involved were selected and classified. These were then translated into questions which might be used to test the capacity of the worker.

In addition to the oral test, here described, there were picture and performance tests. "The picture test required the candidate to identify certain technical processes and details relating to the trade," and the performance test "required the candidate to carry through some operation, or construct some piece of work, which involved the essential processes of the trade."

Raymond Dodge points out the fact that

These tests standardized for the first time in America the classification of novices, apprentices, journeymen, and experts in the most important trades. The scientific care with which these trade tests were prepared may be indicated by the fact that each test before it was adopted passed through a process of development, trial, and evaluation consisting of twelve distinct stages.

A question in one of these finished-up tests for telephone repair men is given by Randall in the *American Magazine* for April, 1919:

Some of the questions (the trade test questions) are very interesting. For example here is one that will set off a journeyman telephone repair

man from an apprentice: "Why is it that when a subscriber tips the telephone instrument in talking, the party at the other end does not hear so well?"

The answer is that the sound box in the instrument contains a lot of little carbon granules which, when put under pressure by the sound waves of the voice, transmit electricity. The harder the pressure the more electricity they transmit, and the better the voice is carried. Tip the instrument, and the granules, which are loosely packed, are displaced, and the person at the other end says, "I don't hear, you'll have to speak a little louder."

A journeyman repair man knows that, because he is expected to open sound boxes and fix them when they are wrong. An apprentice is forbidden, under any circumstances, to open a sound box. His functions are limited to taking a faulty sound box out and putting a perfect one in; and he never sees the inside of one of them.

To the oral tests were added picture tests. One of these—the test for typewriter repair men—I myself took. A four-page leaflet was put in my hands, containing on each page a picture of one section of a typewriter. There were twenty questions on this order: "What is the purpose of the screw marked B?" "If your carriage was running too slow what part of the machine would you adjust?" The test proved that as a typewriter repair man I rank as a low apprentice—which is about right.

In the same concrete fashion, Randall gives an example of a performance test—one for an automobile repair man. In this case the man was a "frame-up"—a person coached for the occasion just to see if he could not weather the automobile test, though in fact only a novice. Randall says:

He appeared in camp, and on the oral tests made a perfect record, which was so unusual as to excite the admiration of the examiner. The result was that he was led into a tent where a certain part of an automobile lay on the table in pieces, and left to put it together. The examiner discovered him a half-hour later. The part was screwed together and looked pretty workmanlike. But the candidate had forgotten entirely to put in any packing, and he was cudgeling his brain to discover what the two springs and a bolt for which he had found no place could possibly be intended for.

If both the tests for general intelligence and the trade tests could be incorporated in a vocational guidance program for the school and the college it would be possible to estimate the individual's all-round capacity as well as any special capacity that he might have. The trade tests to be used with novices or vocationally untrained persons, as would be the case here, would have to be framed to sound native bent, and not to sound (as was the case in the Army) the capacity the person had by virtue of specific vocational training. Not much has so far been done along this line and it may be too much to expect that a great deal can be done. Professor Seashore of the University of Iowa seems to have succeeded in testing for musical ability, and there are a number of men who are busy trying to contrive tests that will have forecasting value in other directions. Dean Schneider of the College of Engineering, University of Cincinnati, is sceptical and maintains that the only way to test for vocational fitness or unfitness is "on the job." It may be, however, that the remarkable success of the trade tests in the Army—confuting the sceptic—will have both a heartening and enlightening effect, and that in consequence real things will be achieved before many years in creating and applying similar tests in educational institutions.

With respect to the general intelligence tests, it seems fair to say that as a rule they do really test, though in a more or less rough way. As adapted for military use (under the name Army recruit test) they counted for something. Thorndike, one of the men who figured prominently in this adaptation, and the man into whose hands was given the preparation of the tests for entrance to Columbia University, while acknowledging the large possibility for error in the results obtained through the use of tests for general intelligence, still holds that "the test score may always be of great value, since it is a clear addition to the available impressionistic knowledge; it taps a new source of information."

A few of the tests in which most faith is placed may be added here. They are of such rank as to have been closely patterned after in the Army. Reference to the army tests can only be

indirect as their publication is forbidden under penalty. These examples are taken from Terman's *The Measurement of Intelligence*.

First, the "dissected-sentence" test. The sentences are to be put in right order.

- (a) For the started an we country early at hour.
- (b) To asked paper my teacher correct I my.
- (c) A defends dog good his bravely master. . . . false true

In the corresponding army test, which contained false as well as true statements, the men had not only to rearrange the disarranged words but had also to indicate whether true or false, by underlining as in sentence (c) above.

A second test is that of "detecting absurdities," used by the army also, only with modified content and with somewhat different instructions. In the Army, those taking the test were told to write the letter "f" before each of the statements which could not possibly be true.

(a) A man said: "I know a road from my house to the city which is downhill all the way to the city and downhill all the way back home."

(b) An engineer said that the more cars he had on his train the faster he could go.

(c) Yesterday the police found the body of a girl cut in eighteen pieces. They believe that she killed herself.

. . . . .

The following test, framed for testing salesman, and closely parallel to one of the army tests, is given by Bruce Barton in the *American Magazine* for March, 1919. There is a time limit set as an index of mentality of different grades. For example, "to take less than 100 seconds is to be in the superior 25 per cent." The individual is graded also on accuracy. The test plainly calls for variegated mental behavior, such as close observation, the ability to hold several things in mind at once, careful and quick use of one's judgment, etc.

With your pencil make a dot over any one of these letters F G H I J and a comma after the longest of these three words: boy mother girl.

Then, if Christmas comes in March, make a cross right here . . . . .  
 but if not, pass along to the next question, and tell where the sun rises.  
 . . . . . If you believe that Edison discovered America, cross out  
 what you just wrote, but if it was some one else, put in a number to  
 complete this sentence: "A horse has . . . . . feet." Write yes,  
 no matter whether China is in Africa or not . . . . .; and then  
 give a wrong answer to this question: "How many days are there in a  
 week?" . . . . . Write any letter except g just after this comma,  
 and then write no if 2 times 5 are 10 . . . . . Now, if Tuesday  
 comes after Monday, make two crosses here . . . . .; but if not  
 make a circle here . . . . . or else a square here . . . . . Be  
 sure to make three crosses between these two names of boys: George  
 . . . . . Henry. Notice these two numbers: 3, 5. If iron is heavier  
 than water, write the larger number here . . . . ., but if iron is  
 lighter write the smaller number here . . . . . Show by a cross  
 when the nights are longer; in summer? . . . . . in winter?  
 . . . . . Give the correct answer to this question: "Does water  
 run uphill? . . . . . and repeat your answer here . . . . . Do  
 nothing here ( $5 + 7 =$  . . . . .), unless you skipped the preceding  
 question; but write the first letter of your first name, and the last  
 letter of your last name at the end of this line: . . . . .

There is need for improvement in the general intelligence tests both in their character and in their use. Thorndike points out the fact that they are not, as their name might indicate, tests of "all intellectual abilities," but only of such abilities as are involved "in learning from lectures and books and dealing with ideas and symbols." He says, illustrating his point:

In the army test Alpha, a test whose data are largely words and numbers and whose score is largely determined by speed, stenographers and typists score enormously better than tool makers, gunsmiths and locomotive engineers, etc., and almost on a level with civil and mechanical engineers and physicians.

It is his opinion, therefore, that "our present standard tests of intelligence need to be greatly extended and improved; and expectations from them need to be kept modestly in line with the facts." One other caution may be appended, namely, that not even vocational psychology can do more toward guiding

the individual in choosing a vocation than to point out the direction in which it appears his nature will block the way with least physical and mental and temperamental handicaps. He may have sufficient unmeasurable will power, or tenacity, or grit to succeed though he goes into a vocation for which he seems least fitted, but he can hardly succeed so well.

Finally, it may be said that the thing which holds out the most promise for the actual realization of the vocational psychologist's dream is the increasing establishment in educational institutions of a personnel bureau, corresponding to a similar bureau in the Army. This will give vocational guidance an official standing, and all the means and methods available will be laid hold of and be turned to account or thrown overboard. The bureau will make use not only of the technique at hand, but "will initiate and encourage research" to the end that trade (vocational) tests may be adapted and invented, the general intelligence tests "be expanded and improved," and other things be done that through vocational guidance "the pupil (and the student) may be helped to discover his own capacities, aptitudes, and interests, may learn about the character and conditions of occupational life, and may himself arrive at an intelligent vocational decision."

## THE USE OF MODELS IN THE INTERPRETATION OF DATA FOR DETERMINING THE STRUCTURE OF BEDDED ROCKS

MAURICE G. MEHL

Of the various ways to describe the structure of sedimentary beds graphically, that of showing the configuration of the datum bed by contours is by far the more common and, for most cases, altogether the more satisfactory method. Ordinarily the structural contour map is drawn from irregularly scattered observations—elevations on a *key bed* or on other horizons from which the elevation of this bed may be calculated.

At best the determination of the structure of a region is an approximation. It is rare indeed that a single bed has unlimited exposures over a large area and even with supplementary observations from sub- and superadjacent beds, within a comparatively large proportion of almost any region, no data are to be had. Usually, then, the observations are closely crowded along the limited outcrops and are relatively far apart over most of the area.

Although in general the principles of contouring topography and structure are the same, the details are somewhat different. Since topographic contours attempt to represent accurately the configuration of a surface, every point on that surface is a valid observation and the greater the number of observations the more accurate the resulting contour map. In contouring the structure, although the contours represent a certain condition of the bed it is not the configuration of its surface. What is to be shown is the *structural attitude*, the attitude of the *general plane* of the bed as it has been modified by diastrophism alone. This is not necessarily the upper or lower surface nor even the present attitude of the general plane of the bed as is pointed out later.

One cannot always be sure, for instance, that an elevation on a bed indicates its structural attitude. Within a region of even moderate relief, if the rock series has the normal complement of shales, there is abundant opportunity for their creep or slump with a consequent down-slope bending of the competent beds. One has only to observe this tendency of limestones to conform to the slope of the hill, as it is shown in a fresh cut across a ridge, to realize the possibility of error in this direction.

As a rule, the top of some conspicuous bed is selected as the datum plane and the observations are confined to this horizon as fully as possible. Few beds maintain their full thickness for any considerable distance, however, and often they are notably irregular. In Wilson County, Kansas, the writer has observed the Stanton limestone reduced from more than 30 feet in thickness to nothing within comparatively short distances. Or again, in Anderson County, Kansas, a Sub-Allen limestone which forms a conspicuous cap of as much as 40 feet in thickness over the ridges of a considerable area is very thin or entirely lacking within half a mile from what is essentially its greatest development.

Obviously, closely spaced observations on such an irregular surface do not give a true picture of the structure of the region. If the datum horizon is displaced 5 feet by slump or the irregular surface of the bed, a decidedly abnormal dip is indicated between this point and another observation point nearby which is taken on the properly related plane. An error of 5 feet if distributed over a large distance is not far from the true configuration of the datum bed. It would appear that observation points can be spaced too closely for the accurate determination of the structure.

There is also some question as to the desirability of showing other than the larger features in the configuration of the beds in an attempt to show the structure. Even if one could be sure of the correctness of the closely spaced observations it is doubtful if the minor changes in dip which these observations show would affect the generally parallel beds at any appreciable distance above or below the datum bed.

Granting, however, that all the observed elevations do indicate the true *effective structure*, there is no assurance that the data will be interpreted in a like manner by two different workers. In the writer's experience, a dozen students using the same data will present nearly as many variations in the interpretation of the structure. With common methods there seem to be always several possible interpretations of the same data, although but rarely more than one logical interpretation presents itself if the observation points are in any sense adequate.

An excellent illustration is to be found in a discussion by K. C. Heald.<sup>1</sup> In this discussion it is pointed out that two

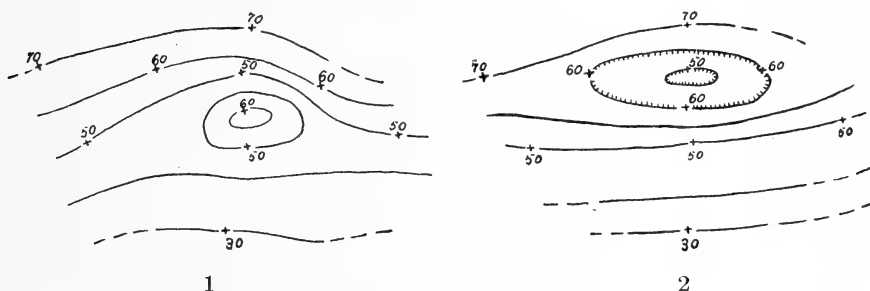


Fig. 1. Structural contour map of a region in which data are lacking at certain critical points. Cross marks with figures are observation points on the datum bed. (After Heald.)

Fig. 2. Structural contour map of the same data as presented in figure 1. Under the methods commonly employed this almost opposite interpretation of the data is permissible if not even logical. (After Heald.)

almost opposite interpretations may be made from the same data. Figures 1 and 2 show the same elevations with an entirely different interpretation. Aside from the fact that the structure shown in figure 2 is a very exceptional expression of deformation, there is apparently no reason why either of these interpretations might not be considered correct.

In determining the structure of a region much must always be taken for granted. It is assumed, for instance, that between two adjacent observation points the dip is essentially uniform. This

<sup>1</sup> Geologic structure of the northwestern part of the Pawhuska Quadrangle, Oklahoma. U. S. G. S. Bull 691 C, p. 80-81, 1918.

assumption is necessary if one is to avoid a number of interpretations comparable to the whims of the various workers. Furthermore, this is found to be justified within limits by experience. It is only because of the fact that the datum plane is thought of as a series of intersecting planes, each one comparatively large, that it may be in any sense adequately represented by contours.

For all practical purposes any surface, no matter how irregular, can be resolved into a series of planes. If the surface is curved at

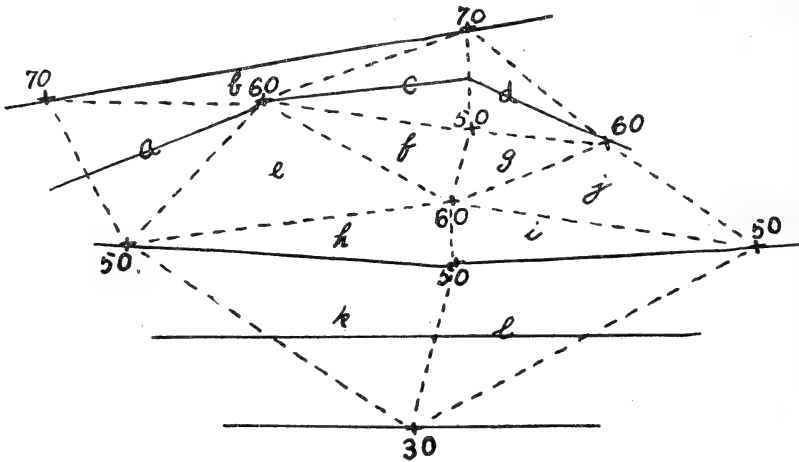


Fig. 3. Application of the *triangle system* to the data presented in figures 1 and 2. The letters A to L indicate the triangles into which the surface is divided by dashed (continuous lines where the edge of the triangles is coincident with a contour) lines. The continuous lines are the contours that appear on the unwarped triangular surfaces.

every part, as in a sphere, the closest representation by planes is that of the greatest number of planes each of the least extent. Three points on a plane, providing they are not in a straight line, fix the position of that plane. If, then, lines are drawn to connect each of three adjacent observation points on a datum bed, that bed will be divided into a series of triangular planes, the greatest number of planes which the data permits. If it is agreed that each set of three points fixes the position of an essentially flat plane which they outline, and this agreement is

arbitrarily adhered to, there can be but slight variation in the interpretation of any structure represented by a series of isolated elevations.

In figure 3, as in figures 1 and 2, the same data are again utilized, but here the principle of intersecting planes is recognized. The observation points are made to outline the several triangular planes *A* to *L*, and each plane is contoured independently. The attitude of the triangles *A*, *B*, *C*, *D*, *K*, and *L* is evident. It is further evident that the "50" corners of the triangles, *C*, *D*, *F*, and *G* are tilted down to form an inclosed depression. Likewise, the point represented by the "60" corners of the triangles *E*, *F*, *G*, *H*, *I*, and *J* represents an elevation. It is obvious then, that there can be but one interpretation of the

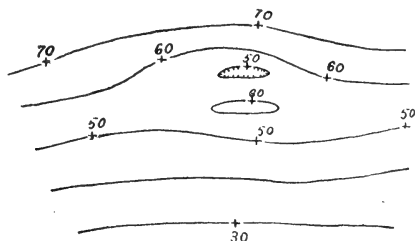


Fig. 4. Structural contour map of the same data as that presented in figures 1 and 2 as it would appear after the sharp intersections of the triangular planes have been "smoothed out."

gross structure of the region. The only possible error is that in the variation in size and the exact position of the small depression marked by the 50 foot contour and the small elevation encircled by the 60 foot contour.

The division of the surface into triangles either graphically or mentally gives the resulting contours a decidedly "stiff" or mechanical appearance. It is evident that the planes must be warped and their intersections "smoothed out" so that any cross section except where broken by faulting shall be free from abrupt changes in direction.

For some time the writer has been practicing a system of modeling which includes all the advantages of the *triangle system* and at the same time eliminates most of its crudities.

## THE CONSTRUCTION OF STRUCTURE MODELS

As a first step in the construction of the model a base sheet is prepared from the plane table sheets. The observation points are properly located and the elevation of the datum plane indicated at each observation. The sheet is attached to a soft board and at each observation point a peg is driven so that its length represents the elevation of the bed at that point. Obviously the

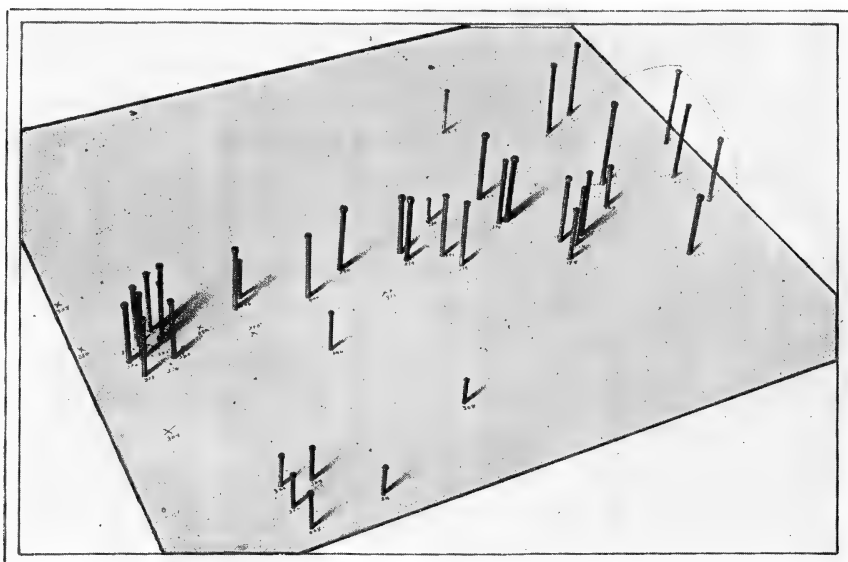


Fig. 5. "Peg" model of the data utilized in the construction of the structure map in Plate XX.

board represents a horizontal reference plane the elevation of which is anything the worker may choose, usually slightly less than the lowest observation point.

After all the pegs are fixed it is a comparatively simple matter to model the surface which they represent by filling in to their tops with fine moist sand or modeling clay. The resulting surface is full of crudities for it is composed of a series of flat triangular surfaces extending between each set of three adjacent points. By slight additions of material in places and the re-

moval of some of the filler in others the surface soon shapes itself into one of broad curves simulating those of the average deformed beds.

There are many short cuts in the technique of model making with which the worker will become familiar after a little practice. The relation of the vertical to the horizontal scale makes no essential difference for if the work is accurately done the resulting contours will always be the same. Obviously, the model must be contoured with the same vertical scale as that used in its construction and the contours must be reckoned and numbered in reference to the assumed elevation of the wood base. The writer has found that on the average a vertical scale which gives a relief of about 3 inches to a model with a base of 16 inches is very desirable. This makes convenient the use of a horizontal scale of 2 or 4 inches to the mile, the usual scales used in plane table work. The models of this size or in units of this size permit the representation of 16 or more square miles, about the average involved in the report of the consulting petroleum geologist.

It is often desirable to preserve the model in the form of a plaster cast. In making casts, care should be taken to preserve the proper relations between the horizontal reference plane and the surface representing the structure. Perhaps the most simple way of accomplishing this is to level the base and then make the negative by pouring plaster of paris over the model (which has been confined by sides of suitable height) till the plaster entirely covers the sand and in its liquid state forms a level surface. When the negative is reversed, insulated, and confined within a suitable frame, the positive may be poured and if the lower side of the reversed negative is horizontal the liquid plaster of the positive will form a flat surface with which the structural surface will have the proper attitude. It has been found that for most work a thin soft soap makes the best insulation between negative and cast.

For contouring the writer has found very convenient an apparatus such as that shown in figure 6. A less elaborate outlay answers the purpose well and is, perhaps, even more accurate.

A long stick with a hole the size of a pencil bored at midlength may be moved about in a plane formed by the edges of a frame about the model and somewhat higher than the latter. The pencil, if fitted closely, may be "set" at the proper distances above the base of the model and the corresponding contours traced.

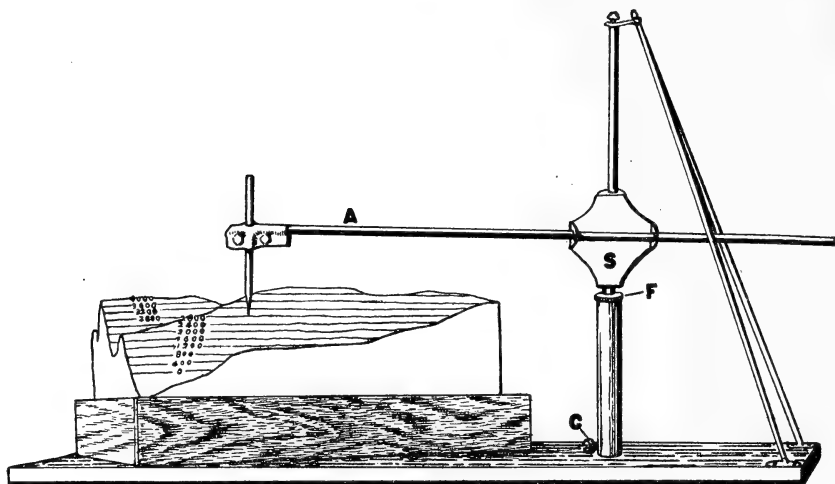


Fig. 6. An apparatus for contouring models and illustrating the use of contours. Constructed in the laboratories of the department of geology, Denison University.

#### ADVANTAGES OF THE MODELS

Contrary to what might be expected, the models promote speed of contouring the field data. The average data may be modeled and contoured and the contours transferred to paper or tracing cloth in less time than is usually required to puzzle out the best interpretation after the ordinary manner.

The model has been found an excellent aid not only in visualizing the data for the geologist but in explaining the nature of the configuration of the beds to those not familiar with contours. As a sales argument, several oil companies have found the models invaluable.

Aside from these advantages, the models have a distinct phase of usefulness. It is recognized by all geologists that some of the data are at times more or less questionable. It is sometimes impossible to determine in the field whether beds have been properly correlated or whether an outcrop shows the true structural attitude. When the structural data of a region are modeled indiscriminately, it is not uncommonly found that certain of the observation points are decidedly out of harmony with those nearby. In other cases there is evident a distinct offset in the surface represented by adjacent sets of observations. It is at once suggested that the elevations of the adjacent regions have been taken on different beds, beds that have been correlated as the same, or the offset may be of such a nature as to be highly suggestive of a fault which was not recognized in the field. In this manner then, the modeling offers a further check on the field valuation of the observation points.

Of special benefit are these suggestions in the interpretation of well-log data. One recognizes the difficulty of interpretation of such data because of the personal equation injected into the record by the driller. His record, if not actually compiled from memory at the end of his tower, is based on the hardness of the materials as indicated by the difficulty of drilling, the color of the sludge and, very rarely, the actual examination of the cuttings. Any fall of material in an "open hole" will modify his record materially and his estimates of the thickness or depth of any formation rarely fits well with the steel tape check.

An illustration of the manner in which the models may be useful is found in checking the data given in connection with the structural map of the Bothwell-Thamesville oil district of Canada.<sup>2</sup> This map, reproduced with slight modifications in plate XX, shows a portion of the structure which has evidently been contoured from well log data from which has been determined the varying elevation of the Delaware limestone. It is clear that unless other data were available than those mentioned by its author, there are many phases of the map which

<sup>2</sup> Williams, M. Y., Oil prospects of Southwestern Ontario, Canadian Dept. Mines, Summary Rept., 1917, pt. E, plate 1.

can not be looked upon as securely established. True, the author of the map has recognized this to some extent, as is indicated by the many dashed contours. Still, there may be questions as to the correctness of interpretation of some of the data in the more definite portions of the map such as the extremely long, narrow syncline near the center of the plate. Apparently there is but a single observation upon which this is based notwithstanding the fact that it is decidedly out of keeping with the regional structure.

There is another striking peculiarity in the manner after which the contours follow the outlines of the "oil pools" in all their sinuosity. One recognizes the common tendency to interpret all data so as to favor a "suitable structure" about producing wells and is inclined to wonder if this is another illustration. Certain it is that so extensive a coincidence of the outline of the oil pools and the contours is out of the ordinary.

The data indicated in this map has been modeled in recognition of the intersecting triangular plane method and the resulting contours are shown in red on plate XX.

In constructing the model all of those observations that were designated as "uncertain" have been omitted because in one case on the original map the elevation of the datum plane varies over 40 feet from the observed "uncertain" elevation. While it cannot be asserted that the resulting contours accurately record the structure of the region, there can be no question but that they do show, with possible minor variations, the most logical interpretation of the data utilized if we are to assume that the data are all valid. As a matter of fact, several of the observations appear decidedly out of harmony with the general attitude of the beds and should call for the most strict investigation in the field before adopted. One striking example is the single elevation upon which the conspicuous, inclosed depression near the east center of the map is based.

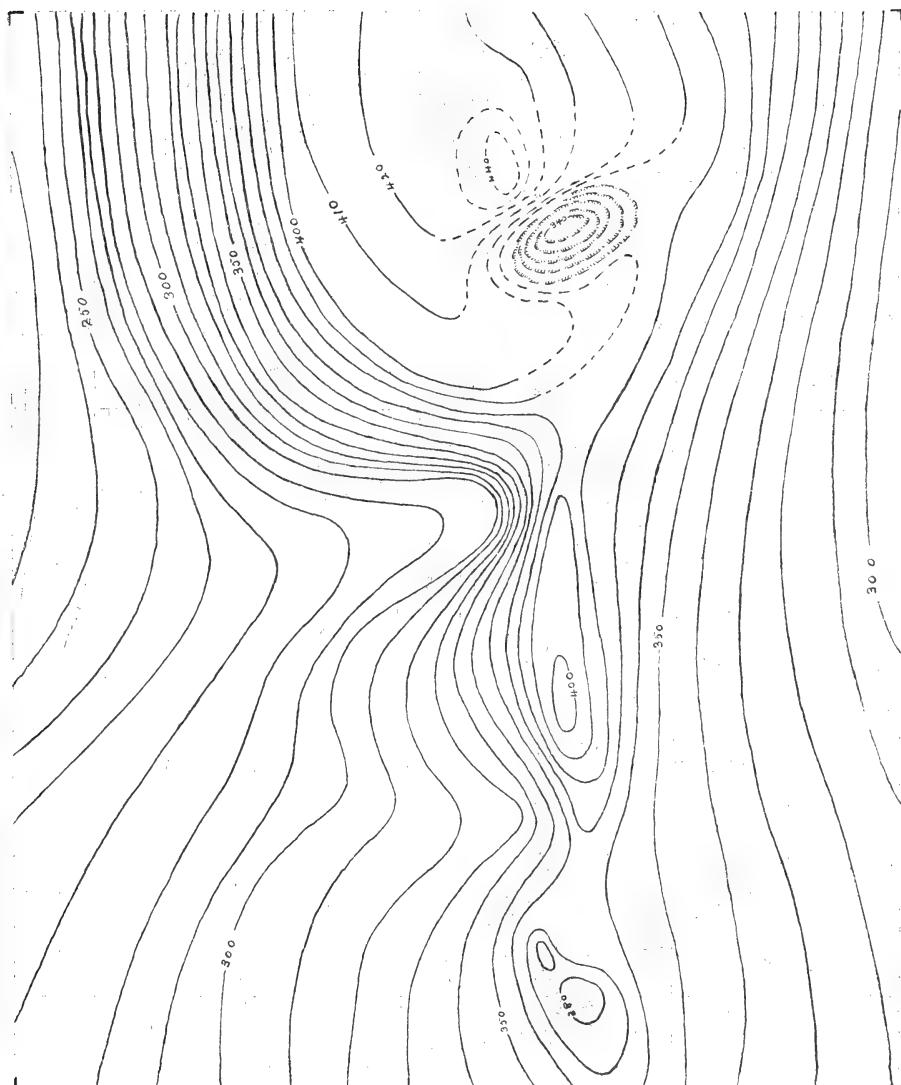
Now while the possibility of eliminating questionable data has been pointed out, it must be recognized that there is great danger in this easy elimination. It must be done with the best discrimination and only after the closest study and after the sug-

gestions have been carefully verified in the field. Otherwise, obviously, there would be a very natural tendency to eliminate all data which did not make for a structure corresponding to the preconceived ideas of the worker. It may be added, however, that on nearly all occasions where the models have seemed to demand the rejection of certain data the further investigations in the field have justified this elimination.

## PLATE XX

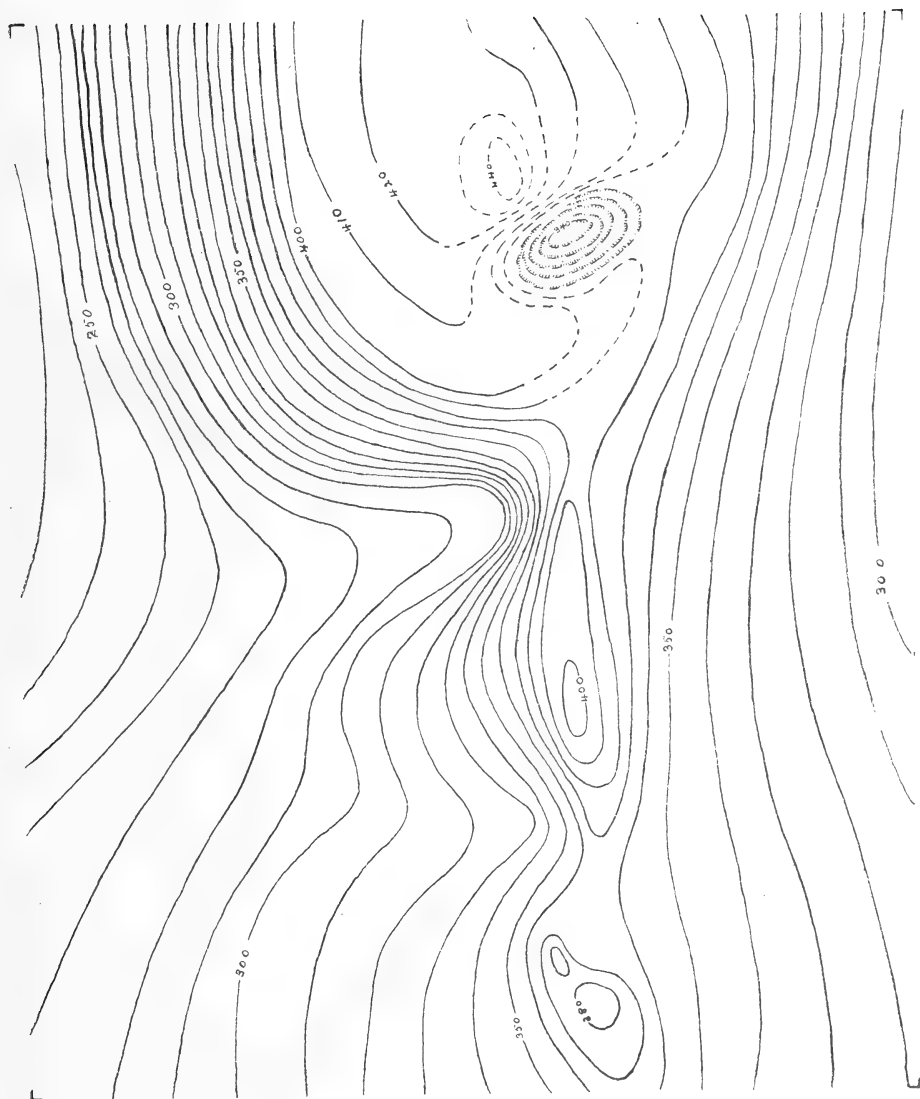
Structural contour maps to illustrate the difference between the common methods of interpretation of structural data and the use of models for this purpose.

—260— Structure Contours  
from Model

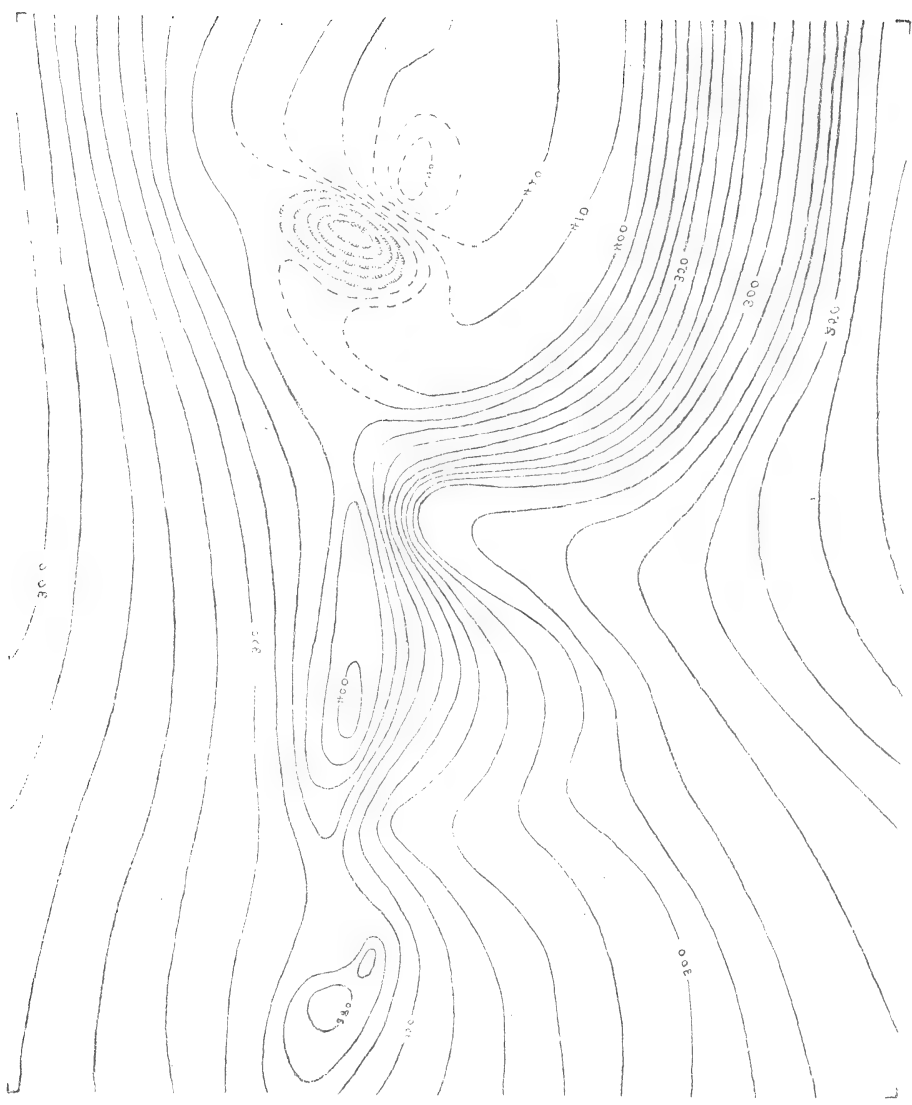


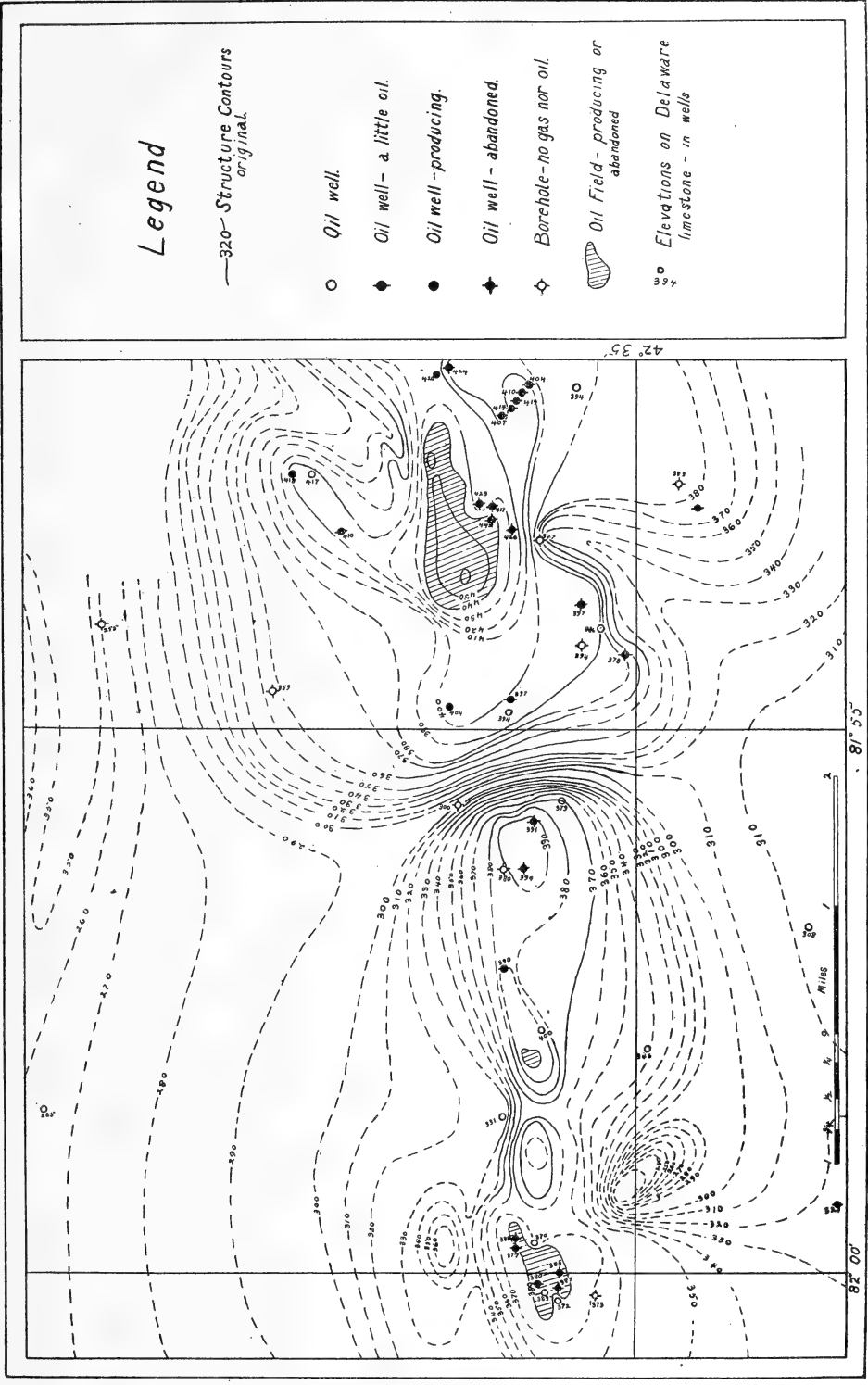


—260— Structure Contours  
*from model*



210000 210000-000-  
level map





MEHL: ORIGINAL CONTOUR MAP



## SOME SUGGESTIONS FOR INDICATING DRILLING OPERATIONS

MAURICE G. MEHL

No doubt it has occurred to all who make use of maps showing drilling operations, that the symbols used for this purpose are not entirely satisfactory. Mr. E. G. Woodruff recently called attention to the advantages in the uniform use of symbols in a paper entitled Notebook form and symbols for petroleum geologists.<sup>1</sup> A few illustrations will serve to emphasize the need for improvement in the methods for describing petroleum and gas development graphically.



FIG. 1

There seems to be no agreement among geologists, draftsmen, and others responsible for the symbols as to how a certain feature, a gas well, for instance, shall be designated. Most state geological surveys have designs of their own selection, and even the geologist as an individual is sometimes partial to a set of symbols that is distinctive rather than useful. Unfortunately, there seems to be no assurance that a design, once having been selected for a certain feature, will be used consistently by its author. The accompanying designs (fig. 1) will give some idea of the great variety in the symbols used for a single feature. As the source from which these designs were compiled does not include private reports, the list is in no manner complete.

Adding to the confusion is the common practice of using the same design to describe many different features. The symbol

<sup>1</sup> Economic Geology, vol. 14, no. 5, p. 424, 1919.

for a gas well, for instance (fig. 1, d), has been used in published reports alone to indicate fully a dozen different conditions such as "Gas well," "Abandoned gas well," "Water sand," "Oil well spoiled," "Stopped above sand," etc.

Any set of symbols, if it is to be universally adopted, must satisfy certain strict requirements. Most of these qualifications are obvious, but certain of the more important are reviewed herewith.

#### SIMPLICITY OF DESIGN

Simplicity is undoubtedly one of the most important considerations. In the first place, to be most useful, the symbols must involve the fewest possible number of lines. A complicated design will not permit the reduction that is often necessary or desirable. When it is realized that there are occasion-



FIG. 2

ally over one hundred wells within a square mile, and that it is not uncommon for maps to be reproduced on a scale of one inch to the mile or less, there can be no doubt but that many designs in common use are not well fitted for all scales.

Even though the maps are reproduced on a sufficiently large scale, the designs are often so complicated as to appear very similar and are, therefore, readily confused in a cursory glance. Designs that depend for their distinctness on the difference in length of component lines or the addition of a ray to a many rayed figure are not desirable. Clearness of design is closely associated with the numbers of lines involved.

To obtain clearness of design some have adopted a set of distinctive figures such as circles, squares, crosses, pentagons, etc. While such figures stand out conspicuously for the most part, they are far from mechanically simple. As a rule they involve "irregular angles" and a large number of operations.

Distinctive, but mechanically complex, designs are shown in figure 2. Any attempt to use these symbols on a large scale requires a great amount of labor or reduces the drawing to freehand work, which is, as a rule, quite unsatisfactory.

#### FLEXIBILITY

To be of greatest use, a map showing oil and gas development must be kept up to date. In order that development which is today designated as a location may be changed to an oil or gas well or a dry hole when the test is completed and may be indicated as an abandoned producer at a later time, each symbol used must be such that by simple additions it may be changed to any other design that might be required in the normal history of the well.

#### LOGICAL DESIGNS

Any development map is likely to show a considerable number of different features. In reality, however, the information conveyed comes under one of three large heads: producing wells, nonproducing wells, and locations. Each of these types requires a distinct symbol, and inasmuch as a producer is predominantly either oil or gas, a distinction must be made between these two. The result is that four primary symbols form the basis for all designs that may be required.

Very commonly a well produces both oil and gas. The symbols for each must be such that they can be combined readily so as to produce a single, self-explanatory figure. The addition of half the symbol for a gas well to that of an oil well tells clearly that the producer is predominantly an oil well but with an appreciable amount of gas. Or again, the combination of the total essentials of the oil and gas symbols should convey the information that the oil and gas are equally divided in the well.

Nonproducing wells may be dry holes or abandoned producers. The reasons for nonproduction may be of great variety, and it is often desirable to record these reasons. It is important to know, for instance, that oil in quantities too small to be recovered

with profit, has been struck. The essential idea is that the well is a nonproducer, however, and the nonproduction symbol must be utilized. The proper designation for such a condition is logically half the symbol for an oil well plus the symbol for a nonproducer.

A dry hole is logically a combination of the symbols for a location and nonproduction. It is true that many other details concerning a dry hole are interesting and often important, such, for instance, as the presence or absence of a sand, the nature of the sand, the presence or absence of water, the adequacy of the test, etc. It is very doubtful, however, whether such details should be recorded on a development map except in the most special cases. As a rule the map is a compilation from many sources and not the record of the compiler's direct observation of the drilling. To be of real value, the statement that a certain dry hole does not mark an adequate test, reasons for this conclusion are necessary. Apparently a written explanation is more desirable than a special symbol for many of the details concerning a nonproducing well.

"Location" usually means actual drilling or good evidence that drilling will be started soon—the erection of a drilling rig, for instance. Very often a map is well marked with "locations" which are to be construed as meaning that they will become drilling locations in the ordinary sense if the "drilling well" proves profitable, if more stock is sold, or if the fancy of the operator does not change; very indefinite locations at best, and usually calculated to mislead the uninformed. If it is desirable to distinguish between actual drilling locations and prospective tests, it is probably well to use a definite symbol for a drilling well and portions of the same symbol to designate the varying degrees of probability that drilling will be carried on seriously at a later time.

#### THE UNI-COLOR SYSTEM

A great variety of simple symbols is to be had by the use of colors and in many cases a multi-color scheme is employed to good advantage. In most "pin systems" for keeping a record

of development on wall maps, pins with heads of various colors show in a striking manner the trends of production. It is clear, however, that for a set of utility symbols a multi-color system cannot be used successfully, because the cost is in many cases prohibitive, and because in the common reproduction by blue-printing or photography, only black and white symbols may be utilized.

<i>Location.</i>	○ <i>Inadequate Test.</i>	⊙
<i>Dry Hole.</i>		⊘
<i>Show of Oil.</i>		⊙
<i>Oil Well.</i>	● <i>The Same - Abandoned.</i>	●
<i>Show of Gas.</i>		⊘
<i>Gas Well.</i>	⊙ <i>The Same - Abandoned.</i>	⊙
<i>Oil Well with Show of Gas.</i>	● <i>The Same - Abandoned.</i>	●
<i>Oil and Gas Well.</i>	● <i>The Same - Abandoned.</i>	●
<i>Gas Well with Show of Oil.</i>	⊙ <i>The Same - Abandoned.</i>	⊙

FIG. 3

## THE SUGGESTED SYMBOLS

In figure 3 is suggested a set of symbols thought to fulfil adequately the requirements as outlined above. There is no radical departure from the present practice, for most, if not all, of symbols are in common use. In one instance, the symbol for a gas well, it has been necessary to alter a generally accepted design. However, inasmuch as the essentials of the design are the same and certain complications are avoided, the change should

not be annoying. Especially is this true in that the substitute design requires fewer operations. All are mechanically simple and require but a few operations. They are in a very real sense self-explanatory and logical, and are of such a nature as to be reproduced readily on either large or small scale.

The "Inadequate Test" symbol of figure 3 illustrates the type of variation from the generalized "dry hole" symbol which permits the indication of a large number of details. By the substitution of such letters as W, C, and N, details like "water sand," "close sand," "no sand," etc., are recorded. Regardless of the detail indicated by the letter, the essentials are the same—a nonproducing well in which neither oil nor gas was encountered in appreciable quantities.

Frequently it is desired to distinguish between wells producing at different horizons. It has been the writer's experience that this and similar data can be shown with less confusion by placing a Roman or an Arabic reference numeral against the regular symbol than by the use of special designs such as have been suggested.

# THE KIMMSWICK AND PLATTIN LIMESTONES OF NORTHEASTERN MISSOURI

AUG. F. FOERSTE

## 1. THE TERMS PLATTIN AND KIMMSWICK AS USED IN THE GEOLOGY OF MISSOURI

The Champlainian or Mohawkian strata of Missouri may be divided into two major lithologic divisions: a lower very fine grained limestone in which usually no individual grains can be recognized even with the assistance of a lens, and an upper, distinctly granular limestone which at some horizons is even coarsely granular, and more or less crystalline.

In the *Geology of Missouri*, published by Prof. E. B. Branson in 1918 as number 15 of volume 19 of the *University of Missouri Bulletin*, the lower fine grained limestone is identified as the Plattin formation, while the overlying distinctly granular limestone is identified as the Kimmswick limestone, both names being applied in a much less restricted sense than that advocated at present by E. O. Ulrich, the original author of these names. This will become evident on referring to plate 2 among the *Correlation Tables* at the close of *Bassler's Bibliographic Index of American Ordovician and Silurian Fossils*, published in 1915; a part of this table is reproduced in a modified form on one of the following pages in section 6 of this paper.

## 2. THE LITHOLOGICAL CHARACTERISTICS OF THE PLATTIN AND KIMMSWICK LIMESTONES

The lower or Plattin limestone appears to have originated as a lime mud deposited as the result of chemical action induced by bacteria. During the deposition of these lime muds quiet waters evidently prevailed. This is shown by the frequent preservation of even the most minute details of surface sculpture on brach-

iopods, trilobites, and other fossils, and by the frequency with which free cheeks are found still attached to the cranidia of trilobites, even the thoracic segments sometimes being present. There is no evidence in these strata of shells having been swept by currents into unnatural positions. There is no evidence of material distinctly of clastic origin. No ripple marks cross the surfaces of the limestone layers, although there is no reason why small ripple marks should not appear locally.

The upper or Kimmswick limestone evidently is chiefly of clastic origin, and might be defined as a lime sand formed by the comminuted remains of shells, bryozoans, and other organisms, more or less altered by crystallization. In the more coarsely granular layers, irregular bedding and cross bedding is not uncommon. Trilobite remains almost invariably are dismembered and more or less broken. The more strongly comminuted organic remains form a matrix in which many other fossils are imbedded. It is remarkable how frequently the surfaces of the imbedded fossils are well preserved. It is evident that comminution of organic remains into lime sand preceded the washing of these sands over the imbedded fossils sufficiently to prevent the surfaces of the latter from being strongly abraded. Periods of comminution and of aggradation of lime sands may have followed each other more or less alternately, or the particles comminuted in one area may have been swept by currents into other neighboring areas.

### 3. THE FOLLEY, BRYANT, AND MCCUNE LIMESTONES, OF KEYES

The first attempt to classify the Champlainian or Mohawkian strata of Missouri and to apply geographical names to their major divisions was made by Prof. C. R. Keyes in 1898, in a paper on Some Geological Formations of the Cap au Gres Uplift, published by the Iowa Academy of Science. In this paper the term Bryant limestone is used for the upper part of the limestone included by Branson in his Plattin formation, and the term Folley is used for the lower part of the same formation. The name

McCune was used for the upper or Kimmswick limestone, as the latter term is used by Branson in the same area.

The term Bryant limestone includes the very fine-grained light blue, relatively thin-bedded, richly fossiliferous limestone, which not only contains a Lowville fauna but also has a Lowville aspect lithologically. The type exposures are along Bryant Creek in the northeastern part of Lincoln County. The total thickness of the Bryant limestone was estimated by Keyes as between 140 and 150 feet. Only the top of this Bryant limestone was studied in Ralls County by the present writer.

The Folley limestone includes the underlying light yellow, heavy, magnesian, poorly fossiliferous limestone. The type locality is Folley, also spelled Foley, a railroad station a short distance north of Winfield, in the eastern part of Lincoln County, where the limestone is exposed in the bluffs west of the Mississippi River. The thickness of the Folley limestone was estimated by Keyes as 65 feet, but later it was recognized that the actual thickness is considerably greater. In Ralls County the Folley limestone is exposed north of the bridge 2 miles northwest of Frankford, on the pike to New London.

Keyes evidently intended to use the term McCune for all of the distinctly granular limestone of Champlainian age occurring above his Bryant limestone. This would make the term McCune equivalent to Kimmswick in the broader sense in which the latter is used by Branson. The type locality is near McCune station, about half way between Frankford and Bowling Green, in the northwestern part of Pike County, the exposures occurring on Penno Creek, directly west of town, where a long bluff lines the eastern side of the creek. The abundance of *Receptaculites oweni* associated with *Hormotoma major* suggests that the actual exposure west of McCune station is limited to the lower part of the upper half of the Kimmswick limestone of Branson, but does not rise as high as the top of the latter. Keyes at first assigned a thickness of only 25 feet to his McCune limestone, and raised this later to 50 feet, but it is known now that the Kimmswick limestone of Branson reaches thicknesses varying from 100 to 125 feet at several points in Ralls County, the county immediately north of that in which the typical McCune outcrops occur.

#### 4. THE TERMS PLATTIN AND KIMMSWICK PROPOSED BY ULRICH

The terms Plattin and Kimmswick were introduced by E. O. Ulrich, and made their first appearance on page 111 of the report of the Missouri Bureau of Mines, 2nd series, volume 2, published in 1904. Here it is stated that the term Kimmswick is proposed for the crystalline limestone exposed at Graysboro, Cape Girardeau, Glen Park, and Kimmswick, and that the term Plattin was to be used for the starta between the Kimmswick and the so-called First Magnesian limestone farther down. Kimmswick is near the northeastern corner of Jefferson County, about twenty miles southwest of St. Louis; the type exposures extend from Kimmswick 8 or 9 miles southward to Riverside. Plattin Creek traverses the southeastern corner of the same county, and is about 18 miles from Kimmswick.

#### 5. THE AUBURN CHERT STUDIED BY BRANSON

In 1909, Prof. E. B. Branson made a special study of the fauna of the chert occurring in the very fine-grained limestone in the vicinity of Auburn, a village in the north-central part of Lincoln County, about 6 miles south of its northern boundary, and probably about the same distance from the type exposures of the Bryant limestone. Although apparently of about the same horizon as the Bryant limestone, the fauna studied by Branson has gone into literature as that of the Auburn chert.

#### 6. CORRELATION TABLES

The terms McCune, Auburn, Bryant, and Folley were founded on exposures in the northeastern counties of Missouri, in Pike and Lincoln Counties. The terms Kimmswick and Plattin were drawn from localities in the southeastern counties of the same state, both in Jefferson County. In Branson's *Geology of Missouri* the terms Kimmswick and Plattin have been extended so as to cover also the exposures earlier defined as McCune, Bryant, and Folley, in the northeastern counties of the state. Judging from the Correlation Tables published in Bassler's Index, Ulrich

and Bassler prefer to use the terms Kimmswick and Plattin in a more restricted sense. A modification of a part of one of their tables is presented here in the following form:

KENTUCKY	SOUTHEASTERN MISSOURI	NORTHEASTERN MISSOURI	MINNESOTA AND NORTHERN IOWA	BRANSON'S GEOL. OF MISSOURI
		McCune	Stewartville	Kimmswick
Curdsville		Prosser	Prosser	
	Kimmswick			
Clay shale		Auburn	Decorah	Plattin
Tyrone	Plattin	Bryant	Platteville	
Oregon		Folley		

The preceding table suggests that in Champlainian times north-eastern Missouri formed part of the northern Mississippi valley province, including Minnesota, Wisconsin, and northern Iowa. While considerable lithological differences are noted in passing from northern Iowa across a long gap into northeastern Missouri, a considerable part of the northern fauna may be still recognized as far south as northeastern Missouri. It is not certain, however, that the typical Kimmswick fauna of southeastern Missouri passes across the gap in northern Warren and southern Lincoln Counties into northeastern Missouri. This can be determined only after it has been ascertained definitely what are the characteristics of this fauna, not at Thebes but at Kimmswick, the type locality. Bassler lists only 4 species from the Kimmswick: *Comarocystites shumardi*, *C. obconicus*, *Echinospaerites aurantium*, and *Eurydictya calhounensis*. None of these species is known at Kimmswick, and the first three are regarded as belonging beneath the lowest strata exposed in the Thebes section.

If in Champlainian times there was an east and west barrier across the central part of Pike county in the area now traversed by the Cap au Gres fault, such a separation of northern and southern faunas might have been operative at various times and

in varying degrees. It may be noted, for instance, that the characteristic cystid, *Comarocystites shumardi* (see 4 in Description of species), described from the Kimmswick of Cape Girardeau, in southeastern Missouri, was found by the writer also in the large quarry northwest of West Kimmswick, 85 miles northwest of Cape Girardeau, but the most diligent search failed to reveal this fossil in Pike or Ralls County, in northeastern Missouri. Moreover in Bassler's Index, *Echinosphaerites aurantium* is listed from the Kimmswick of Missouri, presumably from Cape Girardeau in the southeastern part of the state, but no trace of this fossil has been found in the northeastern part of that state.

#### 7. STUDIES OF ONLY ONE LOCAL AUBURN AND ONE LOCAL KIMMSWICK FAUNA PUBLISHED SO FAR

Unfortunately, only two studies of the Champlainian faunas here under consideration have been published so far. The first of these is a detailed study by Prof. E. B. Branson of the fauna of the Auburn chert, as exposed along a road side east of the village of Auburn, in the north central part of Lincoln County. This study was published in 1909, in volume 18 of the Transactions of the Academy of Science of St. Louis. The following year, in 1910, Prof. T. E. Savage published a detailed study of the stratigraphic succession of the faunal elements of the Kimmswick limestone as exposed along the Mississippi River, three-fourths of a mile south of Thebes, in Illinois. This famous locality is only about 6 or 7 miles southeast of Cape Girardeau, on the Missouri side of the Mississippi River. Both of these studies are confined to single formations as exposed at single localities. No corresponding faunal studies have been published of the McCune, Prosser, Plattin, Bryant, or Folley limestones of Missouri or of the adjacent parts of Illinois.

## 8. RECENT STUDIES OF CHAMPLAINIAN FAUNAS IN NORTHEASTERN MISSOURI

Recently the writer took advantage of an opportunity to study in more or less detail several horizons among the Champlainian rocks of Ralls County and of the adjacent parts of Pike County, Missouri. These horizons included all of those included by Branson under the term Kimmswick, used in the broader sense. In addition, only the top of the underlying Plattin limestone was studied with any care. No fossils were found in the overlying Buffalo or Maquoketa clay shales in those parts of Ralls County where these shales were present. At most localities in this county, the Kimmswick of Branson is overlaid directly by the Devonian. Farther southward, in Pike County, the Maquoketa is sparsely fossiliferous.

In the area under investigation, the Champlainian strata are exposed along the Salt River and its tributaries. Since interest was centered chiefly on the Kimmswick limestone, using this term in its broader sense, this limestone will be discussed first.

## 9. THE FAUNA OF THE KIMMSWICK LIMESTONE, SOUTH OF THEBES, ILLINOIS

About three miles south of Thebes, Illinois, there is a conspicuous exposure of crystalline limestone along the east bank of the Mississippi River. The fossils listed by Professor Savage from this locality are recorded in the accompanying table. Section *a* begins at water level, and section *o* occupies the highest position stratigraphically. The thickness of the different parts of the section is recorded in the table in feet and inches. A total thickness of almost 70 feet of strata is exposed. Of this thickness the lower 20 feet includes the more fossiliferous portion, to which the overlying 50 feet apparently does not contribute any new important faunal element.

It will be noted that neither *Comarocystites* nor *Echinosphaerites* are listed by Savage from this Thebes locality, although both occur at Cape Girardeau, and *Comarocystites* has been found as far north as the large quarry northwest of West Kimmswick.

This suggests that the Kimmswick south of Thebes and the Kimmswick at Cape Girardeau and at West Kimmswick may not be identical stratigraphically.

The fossils listed in the last column of the table, under the letters *LR*, were obtained on Little Rock Island, northwest of Thebes, and evidently contain about the same fauna as the lower strata examined by Savage at the locality south of Thebes.

#### 10. KIMMSWICK FAUNA IN RALLS COUNTY AND IN NORTHERN PIKE COUNTY, MISSOURI

The exposures at the Henry Hamilton, Big Cave, and Wood Cave localities are in direct contact with the top of the Platin, and represent the lowest Kimmswick exposed in the Salt River area. The lowest exposure along the Sanders branch, locality 1, is supposed to begin about 15 feet above the base of the Kimmswick. Locality 7 forms the top of the section. The rise of the stream channel is at a rate so small that no exact measurements can be made readily and those here furnished, beneath the locality numbers, are mere estimates.

A comparison of the lower part of the Sanders branch section, including localities 1, 2, 3, and 4, with the Kimmswick limestone section south of Thebes, Illinois, shows a considerable similarity of faunas, including such forms as *Clitambonites* sp., *Dinorthis meedsi*, *Dinorthis pectinella*, *Parastrophia hemiplicata* var., *Amphilichas cucullus*, *Ceraurinus* cf. *scofieldi* or *trentonensis*, and *Remopleurides* sp. With this lower part of the Sanders branch section it seems possible to correlate also the Frankford and W. T. Jackson localities, in the northern part of Pike County, owing to the presence of *Dinorthis meedsi* and *Amphilichas cucullus* at the latter localities.

Very little is known of the fauna of localities 5 and 6 of the Sanders Creek section, beyond the fact that *Hormotoma* (?) *major* tends to be more common here, and that various poorly preserved species of *Maclurina*, *Maclurites*, and large forms of *Fusispira* occur here. The limestone at this horizon tends to be more coarsely granular and more crystalline than at other horizons in

the so-called Kimmswick section of Ralls County. The localities at Sugar Creek and at McCune Station, in northern Pike County, evidently belong to the same *Hormotoma* (?) *major* horizon. This *Hormotoma major* zone is the McCune of Keyes, when this term is used in a restricted sense.

The top of the so-called Kimmswick limestone section along Sanders branch is formed by a finer grained limestone containing an occasional poorly preserved *Maclurina* and other fossils known also in the underlying strata. It is overlaid by 5 feet of yellowish clay, followed by 10 feet of fine grained Devonian limestone, an unexposed interval of 7 feet, 6 feet of Devonian sandstone, and a considerable thickness of fine grained Devonian limestone, of which only the lower part is exposed at the locality in question.

At the W. H. Bowles locality, only the top of the Kimmswick is exposed, overlaid by 2 feet of yellowish clay shale, 15 feet of calcareous shale, probably Devonian, and 15 feet of undoubted Devonian limestone. The chief interest at this locality was the presence of a small *Cyclocystoides* near the top of the Kimmswick limestone.

At Hagan's shop, also at three-fourths of a mile east of Shiel, and at a locality a mile northeast of Spalding Springs, all three localities being located along the northwestern line of outcrop of the so-called Kimmswick in Ralls County, Missouri, *Plectambonites gibbosus* occurs in the upper part of the Kimmswick section. The *Plectambonites gibbosus* horizon is regarded as above that of the typical *Hormotoma* (?) *major* zone.

#### 11. CORRELATION OF RALLS AND PIKE COUNTY KIMMSWICK WITH STRATA ELSEWHERE

It has been noted already, on a preceding page, that the strata forming the lower half of the so-called Kimmswick section along Sanders branch may be correlated with those strata south of Thebes, Illinois, which were regarded by Savage as of Kimmswick age. A considerable part of the fossils in these strata occur also in the Prosser of Minnesota, although this may not involve actual identity of horizons.

As far as known, the overlying strata, forming the upper part of the Kimmswick section along Sanders branch, including both the *Hormotoma* (?) *major* and the *Plectambonites gibbosus* zone, are not known to occur south of Pike County. Apparently they are restricted to areas north of the Cap au Gres fault, and have their affinities with the Prosser strata exposed in Minnesota. If *Plectambonites gibbosus* and *Cyclospira bisulcata* are to be regarded as characteristic of the lower half of the *Fusispira* bed of Ulrich, then the highest so-called Kimmswick strata exposed in Ralls County and in the adjacent parts of Pike County do not rise above the Prosser horizons. This view is favored by the extreme poverty of *Maclurites* and *Maclurina* in the upper strata of the so-called Kimmswick in Ralls and Pike Counties.

Since the McCune exposures belong to the *Hormotoma* (?) *major* zone, beneath the *Plectambonites gibbosus* horizon, it appears necessary to correlate the McCune limestone also with the Prosser of the Minnesota section, at least for the present. When a better knowledge of the fauna of the McCune limestone has been secured it may be necessary to alter this correlation.

On the other hand, the lower Kimmswick fauna, containing *Comarocystites* and *Echinospaerites*, is unknown in Ralls and Pike Counties, in the northeastern part of Missouri. Until this lower Kimmswick fauna is known in greater detail, it must be regarded as practically an uncertain quantity in Champlainian stratigraphy. At present it is assumed to belong below any strata exposed at the locality south of Thebes, Illinois.

## 12. THE FAUNA OF THE PLATTIN LIMESTONE IN RALLS COUNTY, MISSOURI

No fauna has been listed so far from the typical Plattin limestone of southeastern Missouri. In the northeastern part of Missouri, in Ralls County, only those fossils have been studied which occur in the upper part of the Plattin limestone as there exposed, usually within 10 feet of the top of the formation. On comparing the fauna from the top of the Plattin limestone in Ralls County with that of the Auburn chert in Lincoln County, enough differ-

ences are shown to suggest that they may belong to different horizons. Of the new species and varieties described by Branson from the Auburn chert, only *Parallelodus obliquus* and *Pterygometopus lincolnensis* have been identified more or less doubtfully from the Platin of Ralls County.

#### *Faunal lists*

In the accompanying faunal lists all that is known at present of the faunas of the Kimmswick limestone south of Thebes, in Illinois and in Ralls and Pike Counties, in northeastern Missouri, has been tabulated in order to show the similarity of the Thebes fauna to the fauna of the lower part of the Ralls County section. On the other hand the fauna of the top of the Platin limestone in Ralls County and that from the Auburn chert has been tabulated in order to make evident certain differences in faunal content.

In the list of fossils from Thebes, the thickness of the strata is indicated in feet and inches; in the list of fossils from Sanders branch, the estimates are in feet. In the Sanders Branch section, horizons 1 to 4 correspond to horizons *a* to *i* in the Thebes section. Horizons *j* to *o* of the Thebes section contain about the same fauna as the underlying horizons of this section. The column marked L. R. records the species found on Little Rock Island, which is located about 2 miles north of Thebes. Horizons 5 and 6 of the Sanders Branch section form the McCune zone of the Kimmswick and are not represented in the Thebes section. In table 14, exposures corresponding to the lower half of the Sanders Branch section are printed on the left side of the Sanders Branch section, while exposures corresponding to the upper half of the latter are printed on the right. The Pike county sections are separated from the Ralls county sections by a darker line.

The numbers preceding the names of some of the fossils in the various lists indicate the order in which these fossils are discussed in the Description of Species, at the end of this paper.

13. FAUNA OF KIMMSWICK LIMESTONE, THREE-FOURTHS MILE  
SOUTH OF THEBES, ILLINOIS

	(a) 2-6	(b) 3-2	(c) 2-0	(d) 1-6	(e) 1-9	(f) 3-0	(g) 1-6	(h) 2-4	(i) 4-0	(j) 1-6	(k) 8-6	(l) 4-0	(m) 7-0	(n) 12-0	(o) 15-0	(L R) 12-0
<i>Receptaculites oweni</i> .....	X				X			X			X					X
<i>Clitambonites sp.</i> .....	X															
<i>Crania trentonensis</i> .....													X			
<i>Crania cf. setigera</i> .....																
<i>Dalmanella rogata</i> .....	X	X			X	X	X	X	X	X						X
<i>Dinorthis pectinella</i> .....	X	X	X	X			X	X	X							
<i>Dinorthis sp.</i> .....	X	X			X	X		X	X				X			
<i>Parastrophia hemiplicata</i> .....	X	X	X			X										X
<i>P. hemiplicata var.</i> .....	X	X														
<i>Platystrophia shepardii</i> .....	X	X	X	X		X	X	X	X	X	X		X			X
<i>Plectambonites minnesotensis</i> .....		X														
<i>Plectorthis plicatella</i> .....						X		X								
<i>Rafinesquina alternata</i> .....	X	X	X	X	X	X	X	X	X	X	X		X		X	X
<i>Rafinesquina minnesotense</i> .....							X	X								
<i>Rhynchotrema anticostiense</i> .....			X				X									X
<i>Rhynchotrema increbescens</i> .....			X										X			X
<i>Scenidium anthonense</i> .....	X															
<i>Schizambon sp.</i> .....		X	X													
<i>Strophomena billingsi</i> .....	X															
<i>Str. emaciata</i> .....			X													X
<i>Str. scofieldi</i> .....	X	X	X			X										
<i>Str. trentonensis</i> .....	X	X					X						X			X
<i>Triplesia sp.</i> .....	X	X						X		X			X			X
<i>Zygospira recurvirostra</i> .....	X	X	X		X											X
<i>Cyclonema praecipitum</i> .....	X															
<i>Cyrtolites ornatus var.</i> .....							X									
<i>Holoepa pyrene</i> .....																X
<i>Strophostylus textilis</i> .....	X															
<i>Ambonychia amygdalina</i> .....								X								
<i>Byssonychia intermedia</i> .....																
<i>Orthoceras sp.</i> .....	X	X	X		X			X	X							X
<i>Bronteus lunatus</i> .....	X	X			X			X								X
<i>Bumastus orbicaudatus</i> .....	X	X														
<i>Bumastus trentonensis</i> .....	X	X	X	X	X		X	X	X		X					
<i>Calymene callicephala</i> .....	X	X														
<i>Ceraurus pleurexanthemus</i> .....	X															
<i>Ceraurinus cf. scofieldi</i> .....							X									
<i>Illaenus americanus</i> .....	X	X	X		X	X	X	X	X		X		X			X
<i>Isotelus maximus</i> .....	X				X		X	X					X			X
<i>Lichas</i> .....																X
<i>Amphilichas cucullus</i> .....	X	X					X	X	X							X
<i>Amphilichas cf. robbinsi</i> .....																X
<i>Pseudosphaerexochus cf. vulcanus</i> .....	X															X
<i>Pterygometopus intermedius</i> .....	X	X														
<i>Remopleurides striatulus</i> .....							X									
<i>Remopleurides cf. canadensis</i> .....	X															
<i>Thaleops cf. ovatus</i> .....															X	

14. FAUNA OF KIMMSWICK LIMESTONE IN RALLS AND NORTHERN  
PIKE COUNTIES, MISSOURI

	FRANKFORD-PIKE COUNTY	W. T. JACKSON-PIKE COUNTY	HENRY HAMILTON	BIG CREEK	H. C. WOOD CAVE	SANDERS BRANCH LOCALITIES							W. H. BOWLES	HAGAN'S SHOP	1 MI. E. OF SHIEL	1 MI. N. E. OF SPALDING SPRINGS	SUGAR CREEK-PIKE COUNTY	MCCUNE-PIKE COUNTY
						1	2	3	4	5	6	7						
						15	25	10	30	25	15	10						
Receptaculites oweni.....	X	X		X		X			X	X	X		X	X			X	
Streptelasma corniculum.....														X				
Cyclocystoides cf. halli.....								X		X								
Chasmatopora cf. reticulata..									X									
Constellaria varia.....																		
Rhinidictya mutabilis.....							X											
5. Clitambonites sp.....								X										
Cyclospira bisulcata.....														X				
Dalmanella rogata.....	X	X	X	X	X		X		X									
Dinorthis meedsi.....	X	X	X	X	X		X											
Dinorthis meedsi germana....									X									
Dinorthis pectinella.....						X												
7. Parastrophia hemiplicata var.									X									
8. Platystrophia shepardii.....	X							X										
Platystrophia trentonensis....											X			X	X			
Plectambonites gibbosus.....														X	X	X		
Plectambonites minnesotensis	X	X	X		X		X								X			
Rafinesquina alternata .....								X	X									
10. Rafinesquina deltoidea.....								X	X									
Rhynchotrema increbrescens...	X		X		X		X	X	X									
Strophomena incurvata.....	X							X	X									
13. Strophomena cf. incurvata....								X	X									
Strophomena trentonensis....					X			X	X									
Strophomena trilobita.....																	X	
Ctenodonta intermedia.....								X										
Vanuxemia hayniana.....						X	X											
Fusispira nobilis.....										X	X			X			X	
22. Hormotoma (?) major.....										X	X			X		X	X	
23. Maclurina manitobensis.....											X			X				
24. Maclurites sp.....										X	X		X					
Platyceras cf. depressum.....							X											
Trochonema umbilicatum.....							X											
Actinoceras cf. distans.....								X										
Endoceras proteiforme.....				X							X							
Spyroceras bilineatum.....																X		
Tripteroceras cf. planoconvexum.....																		
32. Amphichelias cucullus .....	X	X					X		X							X		
33. Bumastus cf. billingsi.....								X				X						
34. Bumastus rowleyi nov. sp....								X										
35. Ceraurus cf. trentonensis....									X									
36. Ceraurus cf. bispinosus.....		X					X											
Illaenus americanus.....								+	+		+						+	
40. Proetus cf. undulostriatus....						X												
Pterygometopus callicephalus.	X					X			X									
42. Remopleurides missouriensis.						X			X									

## 15. FAUNA OF TOP OF PLATTIN LIMESTONE IN RALLS COUNTY

	HENRY HAMILTON	YEAGER	CITY QUARRY	SUSAN KENNEY	BUFORD CAVE	J. H. SMITH	CONN'S FORD	BIG CREEK	NORTH OF SPALDING SPRINGS	ALSO IN AUBURN CHEST
<i>Streptelasma breve</i> .....							X			
1. <i>Tetradium fibratum</i> .....		X					X			
3. <i>Cornulites flexuosus</i> .....	X		X		X	X	X			
<i>Orthis tricenaria</i> .....		X	X	X	X		X			X
<i>Pionodema subaequata</i> .....		X	X	X	X		X	X	X	X
<i>Plectambonites sericeus</i> .....		X	X	X	X	X				
9. <i>Zygospira nicolleti</i> .....		X	X		X					
<i>Rafinesquina alternata</i> .....					X		X			
<i>Rhynchotrema minnesotense</i> ..					X		X			
12. <i>Schizocrania filosa</i> .....					X		X	X		
<i>Strophomena incurvata</i> .....	X			X	X	X	X	X	X	X
14. <i>Trematis huronensis</i> .....		X			X		X			
15. <i>Zygospira deflecta</i> .....		X			X					
16. <i>Ctenodonta cf gibberula</i> .....									X	
<i>Ctenodonta nasuta</i> .....					X					X
<i>Ctenodonta nasuta robusta</i> ...					X			X		
<i>Ctenodonta cf. scofieldi</i> .....							X			
<i>Cyrtodonta billingsi</i> .....						X				X
<i>Cyrtodonta huronensis</i> .....		X			X					
<i>Cyrtodonta obesa</i> .....							X			
17. <i>Parallelodus obliqua</i> .....		X					X			
<i>Clathrospira subconica</i> .....		X			X		X			
18. <i>Cyrtolites ornatus minor</i> ....					X		X			
<i>Cyrtolites retrorsus</i> var.....		X								X
<i>Gyronema duplicatum</i> .....							X			
<i>Helicotoma planulata</i> .....		X						X		X
19. <i>Holopea concinnula</i> .....							X			
20. <i>Holopea cf. parvula</i> .....						X	X			
21. <i>Hormotoma gracilis angustata</i>		X	X	X	X	X	X	X	X	X
<i>Liospira obtusa</i> .....		X	X		X	X	X	X		
<i>Lophospira bicincta</i> .....			X		X					X
<i>Lophospira obliqua</i> .....					X					X
<i>Lophospira oweni</i> .....						X	X			X
<i>Phragmolites fimbriatus</i> .....		X					X			X
<i>Salpingostoma buelli</i> .....							X			
<i>Subulites conradi</i> .....		X								
25. <i>Conularia heymani</i> sp. nov...							X			
26. <i>Conularia</i> sp.....			X		X					
27. <i>Hyolithes baconi</i> .....					X	X				
29. <i>Orthoceras</i> sp.....							X			
30. <i>Spyroceras bilineatum</i> .....		X	X	X	X		X			X
31. <i>Tripteroceas planodorsatum</i> ..			X							X
43. <i>Bathyrus spiniger</i> .....		X	X				X			X
<i>Bumastus milleri</i> .....					X		X			X
37. <i>Ceraurus plattinensis</i> .....			X		X		X		X	
<i>Isotelus gigas</i> .....			X				X	X		
41. <i>Pterygometopus lincolnensis</i> ..	X									X
<i>Pterygometopus intermedius</i> ..					X		X	X		X

## 16. THE FAUNA OF THE AUBURN CHERT, IN LINCOLN COUNTY, MISSOURI

The following is a list of the species occurring in the Auburn chert, in the vicinity of Auburn, in Lincoln County, Missouri. Almost all of the species mentioned were listed by Professor Branson in his paper on the fauna of this chert, published in 1909. To this have been added those species which in the body of Bassler's Bibliographic Index are cited from the same horizon and locality; and also a few species found by the writer in the quarry a short distance north of Auburn, on the east side of the main pike. Those found in this quarry are italicized. The new species described by Branson are indicated by \*.

- |                                   |                                      |
|-----------------------------------|--------------------------------------|
| Hindia parva                      | Eotomaria dryope                     |
| <i>Columnaria halli</i>           | * Helicotoma missouriensis           |
| Lichenaria typa                   | Helicotoma planulata                 |
| Streptelasma corniculum           | Helicotoma tennesseensis             |
| 2. <i>Beatricea gracilis</i>      | Holopea insignis                     |
| Dalmanella testudinaria           | * Hormotoma fasciata                 |
| Orthis tricenaria                 | Hormotoma gracilis sublaxa           |
| Pianodema subaequata              | * Hormotoma latiangularis            |
| <i>Rafinesquina minnesotensis</i> | Liospira micula                      |
| Strophomena incurvata             | Liospira progne                      |
| Zygospira nicolleti               | Lophospira fillmorensis              |
| Zygospira recurvirostris          | Lophospira obliqua                   |
| Aristerella nitidula              | Lophospira oweni                     |
| Clionychia lamellosa              | Lophospira perangulata               |
| * Ctenodonta auburnensis          | Lophospira saffordi                  |
| * Ctenodonta costata              | Lophospira spironema                 |
| <i>Ctenodonta logani</i>          | Phragmolites fimbriatus              |
| Ctenodonta medialis               | Strophostylus textilis               |
| Ctenodonta nasuta                 | Trochonema umbilicatum               |
| Ctenodonta oviformis              | Pterotheca expansa                   |
| Cyrtodonta billingsi              | Orthoceras sociale                   |
| Goniophora carinata               | Spyroceras bilineatum                |
| Modiolodon (?) gibbus             | Tripterocheras planoconvexum         |
| * Modiolodon subrhomboides        | Zitteloceras billingsi               |
| * Modiolopsis expansa             | <i>Bathyrurus extans</i>             |
| * Parallelodus obliquus           | Bathyrurus spiniger                  |
| Whiteavesia subcarinata           | Bumastus milleri                     |
| Archinacella patelliformis        | Ceraurus pleurexanthemus             |
| Bellerophon capax                 | Isotelus gigas                       |
| Bucania halli                     | Pterygometopus intermedius           |
| Carinaropsis acuta                | * <i>Pterygometopus lincolnensis</i> |
| Carinaropsis phalera              | <i>Leperditia fabulites</i>          |
| * Cataschisma typa                | * Technophorus bellistriatus         |
| Cyrtolites retrorsus fillmorensis |                                      |

## 17. LOCATION OF THE FOSSIL LOCALITIES IN THE KIMMSWICK OF RALLS AND PIKE COUNTIES, MISSOURI

Frankford; quarried bluff below the level of the railroad, in the eastern part of the town. W. T. Jackson farm; from Frankford  $2\frac{1}{2}$  miles north, then about 1 mile east to a bluff north of the spring east of the farm house; in the southern part of section 24 in R 4 W, T 55 N. Henry Hamilton;  $3\frac{1}{2}$  miles directly north of Frankford, in the center of section 14, along the road northwest of the house, east of the creek. Big Creek; immediately north of the entrance of Newlon branch, on the W. G. Harvey farm, in the western edge of section 29, in R 5 W, T 56 N. Cave on H. C. Wood farm; from New London 1 mile west and then almost  $\frac{1}{2}$  mile north, in the eastern part of section 2.

Sanders branch; in sections 28, 21, and 22, 5 miles northwest of New London. The lowest exposure occurs on the E. E. Priest farm, north of the junction of the two main branches of the creek in section 28, and contains *Dinorthis pectinella*. Northeastward, on the J. H. Luke farm, in the southeastern corner of section 21, *Receptaculites oweni* and *Constellaria varia* are found. These two localities are listed under locality 1 of the accompanying table; the included strata are estimated to have a thickness of 15 feet and to be about 15 feet above the base of the Kimmswick. Locality 2 consists of a thin limestone layer, scarcely  $\frac{1}{4}$  foot thick, full of fossils; it is exposed in the southwest corner of section 22, a considerable distance down stream from the cliff spring west of the home of J. W. Briscoe. This locality is estimated as 10 feet above the top of locality 1 and 15 feet below the level of the Briscoe spring. Locality 3 extends from the Briscoe spring to the road crossing east of the home of John H. Kirchner; its total thickness is estimated at 10 feet. Locality 4 extends from the Kirchner road crossing to the first natural rock dam located on the western fork of Sanders branch on the Kirchner farm, and is estimated at 30 feet. Locality 5 is located at an elevation about 20 feet higher, and includes 5 feet of strata on the M. S. Warren farm, in the northwest quarter of section 22, along a bluff exposure containing *Hormotoma major* associ-

ated with some form of *Maclurites*, but *Hormotoma major* is much more common in the immediately overlying strata. The total thickness of strata here involved is 25 feet. The strata in which *Hormotoma major* is abundant are well exposed at locality 6 on the W. Z. Zink farm, in the northeastern part of section 22. The rock here often weathers into coarse grained slabs with tortuous channels on top, and with more or less irregular cavities along the exposed margins. This coarse grained limestone is 15 feet thick, and is overlaid at locality 7 by a fine grained, richly fossiliferous limestone layer, about one foot thick, overlaid by about 9 or 10 feet of similar fine grained rock, but with very few fossils beyond a single siphuncle of *Endoceras* and several specimens of *Streptelasma corniculum*. The Kimmswick limestone is overlaid here by 5 feet of yellowish clay shale of undetermined age.

W. H. Bowles farm; 2 miles west of New London, on south side of road, on east branch of Doe Run, about  $\frac{1}{2}$  mile above its confluence with the main creek. Hagan's blacksmith shop; 7 miles west of the Oakwood end of Hannibal, and then 3 miles south, south of road crossing at south end of section 13 in range 6 west. Three-fourths mile east of Shiel, near junction of three forks of main creek, in eastern edge of section 20. One mile northeast of Spalding Springs, at locality reached by going  $\frac{1}{2}$  mile northeast from Spalding Springs, and then turning off eastward along a second road, and continuing to the top of the hill land.

Sugar Creek; from Frankford  $4\frac{1}{2}$  miles eastward on the pike to Louisiana, to exposures along the southwestern branch of Sugar Creek, south of the pike. McCune; from the railroad station westward to Peno Creek, and then southward along the creek.

#### 18. LOCATION OF FOSSIL LOCALITIES IN THE PLATTIN OF RALLS COUNTY

Henry Hamilton;  $3\frac{1}{2}$  miles directly north of Frankford, in center of section 14, northwest of house. Yeager farm; 3 miles northwest of Frankford, on east side of pike to New London, a

short distance northwest of the house. City quarry; about 1 mile southeast of New London on one of the main roads crossing Salt River. Susan Kenney farm; 1 mile north of New London, at the top of the bluff northwest of the bridge crossing a southern tributary of Salt River. Buford Cave; on the M. F. Meyer farm, 2 miles west of New London, and then  $\frac{1}{2}$  mile north to a point where the road turns west, near the eastern margin of section 2. J. H. Smith farm; on south side of Salt River, 1 mile northeast of Conn's Ford, near the western edge of section 27, in R 5 W, T 56 N. Conn's Ford; in bed of Salt River, about 4 miles northwest of New London, in northwestern corner of section 33, R 5 W, T 56 N. Big Creek; on the W. G. Harvey farm, about 1 mile northwest of Conn's ford, in the western edge of section 29. Northwest of Spalding springs about 1 mile, at the southern end of section 23 in R 6 W, T 56 N, southwest of the home of H. W. Ogle.

#### 19. UNCONFORMITIES AT TOP OF KIMMSWICK LIMESTONE OF RALLS AND PIKE COUNTIES

In the central and western parts of Ralls County the so-called Kimmswick limestone is overlaid directly by the Devonian. This includes all localities west and northwest of New London. In the eastern part of Ralls County, however, the Buffalo shales, typically exposed along Buffalo Creek, in Pike County, intervene. An excellent exposure of the Buffalo shales is found in the eastern part of section 29, about 3 miles northeast of New London, and about  $1\frac{1}{2}$  miles east of Salt River Switch railroad station. They are well exposed also south of the home of W. H. Benham, on the head waters of the western branch of Peno Creek, about 3 miles south of Frankford, in the southern part of section 15. Here the Buffalo shales are underlaid by coarse grained limestone, 4 feet thick, containing an undescribed species of *Nileus*, (See under section 39 in Description of Species). Another excellent exposure of Buffalo shales occurs 3 miles east of Frankford, on the road to Louisiana. Here a knob formed by the shales contains a large *Rhynchotrema* (See under 11, *Rhyncho-*

*trema rowleyi*, in Description of Species) and a multiplicate form of *Dinorthis* of the *D. subquadrata* group. Further southward and southeastward in Pike county the Buffalo shales are overlaid by Silurian strata, so that the Devonian limestones rest on successively lower strata on proceeding from southern Pike County north and northwestward across Ralls County. The Buffalo shales correspond approximately to the Maquoketa of Iowa. The immediately overlying part of the Devonian limestone corresponds closely to the Wapsipinicon of the same state.

At the same time those upper parts of the Devonian limestone section which contain *Acervularia* appear confined to the more northwestern exposures of Ralls County, extending in a northeasterly direction from Shiel across the central parts of R 6 W, T 56 N. They correspond to the Cedar Valley limestone of Iowa.

The Edgewood formation of Pike and of the immediately adjacent counties, of Silurian age, apparently was deposited in a restricted basin separated from the Silurian of Iowa by some barrier. During the later Devonian, however, the seas of Pike and Ralls Counties may have been connected with those of Iowa, but a barrier extending across the southern part of Pike and the adjacent parts of Lincoln County may have limited these seas southward, cutting them off from the more southern Devonian areas of Missouri.

#### 20. REMNANTS OF EARLY ORDOVICIAN FAUNAS IN THE EARLY SILURIAN OF MISSOURI

One of the most striking features of the Richmond group is the recurrence of Trenton, Black River, and earlier types, frequently after a long absence during the intermediate Eden and Maysville strata. In the Fernvale member of the Richmond from southern Illinois and in the adjacent part of Missouri, *Hebertella lineolata* Savage belongs to the same generic division as the new species described in this paper from the Kimmswick limestone of southeastern Missouri as *Mcewanella raymondi*. In the Thebes sandstone of southern Illinois, *Conularia delicatula* Savage belongs to a group of species known hitherto only from the Trenton of New York (*Conularia granulata* and *C. papillata*), but in-

cluding also the *Conularia heymani* described in this article from the Plattin limestone of Missouri. The little trilobite *Endymionia bellatula* Savage, described from southern Illinois and northeastern Missouri, apparently finds its nearest relative in the Canadian *Endymionia meeki* Billings of Quebec and Newfoundland.

In a similar manner the Orchard Creek shale at the base of the Alexandrian (Medinan) of southern Illinois and adjacent Missouri contains such Ordovician elements as *Cyclocystoides*, *Byssonychia*, *Lyrodesma*, *Phragmolites*, *Isotelus*, and *Ceratopsis*. The *Calymene dubia* of Savage belongs to the same group as *Calymene christyi* and *Calymene platycephala*, from the Richmond and Trenton respectively, for which the writer recently proposed the generic term *Platycoryphe*.

The association of such Ordovician types with others of Silurian character suggests the proximity of southern Illinois and southeastern Missouri, in early Silurian times, to areas in which Ordovician types still thrived. The associated Silurian forms evidently must have originated as some more distant source, and must have entered the eastern Missouri areas only as migrants.

#### DESCRIPTION OF SPECIES

##### 1. *Tetradium fibratum* Safford.

Most species of *Tetradium* of Black River age consist of more or less dissociated groups of cells, while massive growths predominate in later strata.

At the top of the Plattin limestone, in Ralls County, a species with more or less flattened massive growth occurs, but in comparatively few numbers. One specimen, found at Conn's Ford, consists of a circular corallum, 32 cm. in diameter, and 6 to 8 cm. thick. Along the exposed surface the corallites are arranged in straight or curved rows which intersect each other at angles varying from 80 to 90 degrees. Usually about 7 corallites occur in a width of 5 mm., varying locally from 6 to 8 in the same distance. The corallites are more or less quadrate in cross-section, single septa extending inward from the middle of each wall, and almost or fully reaching the center of the corallites. Similar specimens occur at the J. H. Smith and Yeager localities.

## 2. *Beatricea gracilis* Ulrich.

*Plate XXIII, fig. 7*

Stems 6 to 7 mm. in diameter, and several centimeters long, characterized by the presence of granules connected by the characteristic more or less anastomosing lines as in typical *Beatricea*. Strongly convex septal lamellae occur at intervals and occupy almost the entire width of the stems. In the Auburn limestone at the quarry a short distance north of Auburn, in Lincoln County.

## 3. *Cornulites flexuosus* Hall.

Specimens closely resembling the type of *Cornulites flexuosus* (Pal. New York, vol. VII, Supplement, 1888, p. 18, pl. 115, fig. 41), from the Trenton of New York, occur on moderately convex forms of *Rafinesquina alternata*, at the top of the Plattin limestone in the city quarry, at the Henry Hamilton locality, and elsewhere in Ralls County. Usually this species is not listed from below the Trenton.

## 4. *Comarosystites shumardi* Meek and Worthen

*Plate XXII, figs. 24 A, B*

The type of *Comarocystites shumardi* was described from the Kimmswick limestone at Cape Girardeau, in the southeastern part of Missouri. The specimens here figured came from the top of the Kimmswick limestone exposure at the large quarry about  $\frac{1}{2}$  mile northwest of West Kimmswick, in Jefferson County. One specimen consists of a fragment of the theca, bordering on the anal opening, and exposing the interior side. The plates, from this point of view, present a stellate appearance, the rays extending from the center of one plate to the center of one of the immediately adjoining plates. On the sides of the stellate rays the pores open in rows parallel with the crest of the rays. Viewed along the suture planes, between the thecal plates, the pores are elongated vertically and tend to form vertical series. A second figured specimen consists of a single detached plate.

Several additional specimens, consisting of a number of plates still attached to each other, were found at the same horizon.

The *Comarocystites* horizon is regarded as below the Kimmswick strata exposed at the locality south of Thebes, Illinois, which were studied by Prof. T. E. Savage.

*Comarocystites punctatus*, from the Trenton of the Ottawa area, is remarkable for possessing pinuliferous free arms, with plates arranged in uniserial order (Ottawa Naturalist, 30, 1916, October, November, December numbers.) Uniserial recumbent fixed arms occur in *Amygdalocystites* and *Canadocystis*. Such uniserial arms seem to be characteristic of a restricted closely related group of cystids. At one time, this uniserial arrangement of arm plates was regarded by the writer as primitive. However, it is difficult to maintain this opinion in view of the fact that all early cystids whose arm structure is known have the biserial arrangement. *Gogia prolifica* Walcott (Cambrian Geology and Paleontology, IV, no. 3, 1917, p. 68), from the Lower Cambrian of British Columbia, and *Eocystites* (?) *longidactylus* Walcott, from the Middle Cambrian of Nevada have biserial arms. This is true also of *Macrocystella mariae* from the Upper Cambrian of Shropshire of England, and *Lichenoides* from the Cambrian of Bohemia.

##### 5. *Clitambonites* cf. *diversus* Shaler

###### *Plate XXIII, fig. 6*

Only a single brachial valve of *Clitambonites*, exposing its interior, was exposed in the Kimmswick limestone, in the lower half of the Sanders Creek section, in Ralls County.

An excellent pedicel valve was collected by D. C. Barton from the Kimmswick limestone at the Glencoe Lime and Cement Company quarry, at Mineke, in St. Louis County. In this specimen the cardinal area rises 10 mm. above the hinge-line, the latter being 19 mm. wide, and the maximum width of the valve being 24 mm. The cardinal area forms an angle of about 135 degrees with the plane of contact of the two valves. It is regarded as a new species, but more material will be necessary to differen-

tiate it from the Anticostian Richmond species with which this form usually is identified. Specimen preserved at Harvard University.

*Mcewanella* nov. gen.

*Hebertella lineolata* was described by Savage (Illinois Academy of Science, 1917, p. 267, pl. I, figs. 1, 2) from the Fernvale member of the Richmond near Thebes, Illinois, and at Cape Girardeau, Missouri. The same species was described by Eula Davis McEwan as *Platystrophia fernvalensis* (Proc. U. S. Nat. Mus., 56, 1919, p. 428, pl. 50, figs. 1, 2, 3), from the Fernvale limestone at the old quarry southeast of Regenhardt's quarry, northwest of Cape Girardeau, Missouri. This species begins at the beak as a distinctly plicated shell, the plications being distinctly striated longitudinally. Toward the anterior margin the plications become indistinct but the longitudinal striations remain distinct. The median part of the brachial valve is elevated into a fold, and the corresponding part of the pedicel valve is depressed into a sinus.

The anomalous position of this species is indicated by its reference to *Hebertella* by one author, and to *Platystrophia* by a second. By the present writer it is regarded as distinct from both, the sharply defined radial striations being unknown in typical *Platystrophia*, and the distinct plications of the earlier stages of growth being unknown in *Hebertella*. The pedicel valves of both *Hebertella* and *Platystrophia* have deep muscular impressions, those of *Platystrophia* being deeper and narrower. In this respect the species here under consideration resembles *Platystrophia* more closely.

Owing to the occurrence in the Kimmswick limestone of southeastern Missouri of a second species, closely resembling *Hebertella lineolata* generically, the desirability of a separate generic designation for species having this type of structure was increased. Therefore, the name *Mcewanella* is proposed in honor of Miss McEwan, the author of the recent detailed study of the genus *Platystrophia*, cited above.

6. **Mcewanella raymondi** sp. nov.*Plate XXIII, fig. 1*

Only a single brachial valve known, 26 mm. wide at the hinge-line, 20 mm. long, and with a convexity of 9 mm. Valve strongly plicated, the crests of the two median plications being only 3 mm. apart and elevated into a median fold which rises 3 mm. above the bordering depressions. The anterior margin of the shell curves backward 5 mm. along this fold, thus indicating the presence of an equally conspicuous sinus on the pedicel valve. On each side of the median fold of the brachial valve there are five lateral plications, of which the first two are conspicuous, the third is of intermediate size, the fourth and fifth are low, and a distance of about 1.5 mm. intervenes between the fifth plication and the hinge-area. The elevation of the first and second plications is about one millimeter, and their crests are rather abruptly rounded. The entire surface is radiately striated. At a distance of about 5 to 10 mm. back from the anterior margin these striae frequently average about 4 in a width of 2 mm., but nearer the anterior margin, where numerous concentric lines of growth indicate gerontic conditions, the number of these striae may increase to 6 in the same width. The finer details of surface structure are not well preserved.

From the Kimmswick limestone in the Glencoe Lime and Cement Company quarry at Mincke, in St. Louis County, Missouri. Collected by D. C. Barton. Named in honor of Prof. Percy E. Raymond of Harvard University, to whom I am indebted for the loan of this specimen.

7. **Parastrophia hemiplicata** var.*Plate XXI, fig. 4; plate XXII, fig. 4*

Two valves found in the Kimmswick limestone at locality 4 on Sanders branch, in Ralls County, are referred to *Parastrophia* because they present a median septum extending forward as far as midlength of the valve, separating posteriorly into two slowly diverging lamellae such as those forming the narrow spondylium

in *Parastrophia*. There is no indication of sinus or fold, the specimens being small, but along the anterior margin there are traces of short low folds.

#### 8. *Platystrophia shepardi* Castelnau

*Plate XXI, fig. 5*

*Platystrophia shepardi* was figured by Castelnau (Essai Systeme Silurien l'Amerique Septentrionale, 1843, p. 42, pl. 14, fig. 15) from the magnesian limestone of the Menominee River, near its entrance into Green Bay. According to the Geological Map of Wisconsin, published in 1911, this exposure near Menominee might correspond approximately to the Prosser limestone of Minnesota.

The brachial valve here figured was found at locality 3 in the Sanders branch section, in Ralls County, but it occurs also at similar horizons at other localities in Ralls and Pike Counties.

Most specimens are less elongate along the hinge-line, resembling *Platystrophia trentonensis* McEwan, from the Prosser of Minnesota and Iowa.

#### 9. *Zygospira nicolleti* Winchell and Schuchert

*Plate XXIII, fig. 8A, B.*

The largest specimen found so far is 4.6 mm. long, 4.3 mm. wide, and has a total depth of 3.2 mm., the pedicel valve being slightly more convex than the brachial one. The median part of the pedicel valve is angularly arched, and from this median part the sides slope strongly downward toward the lateral margins. The general surface of the brachial valve is convex; anteriorly the median part is depressed into a sinus. Found near the top of the Plattin limestone at the Buford Cave, at the Yeager locality, and elsewhere in Ralls County, Missouri.

This species is related generally to *Zygospira*. Externally it resembles *Protoxega anticostiensis* Twenhofel, from the Richmond of Anticosti, in the broad anterior median sinus on the brachial valve and in the keeled median convexity of the pedicel

valve. In one specimen there is a slight tendency toward the elevation of the anterior sulcus of the brachial valve along its median line, and from this it is assumed that the anterior part of the median elevation of the pedicel valve might be slightly depressed along its median line, but neither tendency finds sufficient expression in any of the specimens at hand to admit of positive observation. *Protozeuga sulcocarinata* Savage, from the Alexandrian (Medinan) of Illinois and Missouri, appears closely related to the Anticosti form. The Plattin species, here under consideration, is supposed to be identical with the Black River species *Zygospira nicolleti*, which was described originally under *Hallina*.

#### 10. *Rafinesquina deltoidea* Conrad

*Plate XXI, figs. 2, 3; plate XXII, figs. 2, 3.*

The small specimens of *Rafinesquina*, here identified as *Rafinesquina deltoidea* (fig. 3), are not distinctly deltoid in form, but they correspond most nearly to the specimen figured by Hall and Clarke under that name (Pal. New York, 8, pt. 1, 1892, pl. 9A, figs. 1, 2), from the Trenton at Jacksonburg, New York. Most of these specimens do not exceed 20 mm. in length, but are so strongly convex as to indicate their full maturity. Abundant at localities 3 and 4 in the Kimmswick limestone of the Sanders Creek section.

A single valve (fig. 2), from locality 4 of the same section, resembles the specimen figured by Hall as *Leptaena* (= *Rafinesquina*) *deltoidea* (Pal. New York, 1, 1847, pl. 31 A, fig. 3a), from the Trenton limestone at Trenton Falls, New York. It is 28 mm. long, 27 mm. wide, and has a convexity of 9 mm.

Larger, and relatively less convex shells, such as those usually identified as *Rafinesquina alternata* (Emmons), also occur at locality 3 on Sanders branch. One specimen is 31 mm. long, 35 mm. wide, and has a convexity of 7 mm.; in other specimens the convexity is even less.

All specimens of *Rafinesquina alternata* from the Plattin limestone of Ralls County are only moderately convex, the convexity usually not exceeding 4 mm.

11. *Rhynchotrema rowleyi* sp. nov.*Plate XXIII, fig. 2 A-D*

Shells of large size, occurring as separated valves with the anterior margin more or less broken off. In the three best preserved pedicel valves, with lateral diameters of 28, 29, and 33 mm., the lengths are estimated at 27, 29, and 33 mm., and the convexities at 8, 8, and 9.5 mm. respectively. Three plications occupy the sinus of the pedicel valve, and five or six plications occupy each side, leaving an unplicated space 5 or 6 mm. wide between the last plication and the postero-lateral angle of the valve. Four plications occupy the median fold of the brachial valve, and four occur on each side, occasionally with a trace of a fifth lateral plication. The plications are crossed at regular intervals by conspicuous and rather coarse concentric striae, of which five or six occur in a length of 5 mm. on the more central parts of the valves and toward the beak. In addition to the coarser striae, some valves show much finer concentric striae, and the latter tend to dominate along the unplicated postero-lateral parts of the valves and also along the anterior, more or less gerontic part of the valves.

The interior of both valves is constructed as in *Rhynchotrema capax*, but the muscle scars are more deeply impressed. Adductor scars impressed in the posterior part of the muscular area, distinctly defined laterally, 3 mm. wide and almost 6mm. long. The remainder of the muscular area is occupied by the diductor scars which are crossed by more or less irregular radiating lines. The posterior part of the diductor scars embraces the adductor scars. The area occupied by the diductor scars is deeply impressed postero-laterally and is fairly distinct even anteriorly; its width is 11 mm., and its length is 12 or 13 mm. The pitted ovarian markings occupy the area between the deeply impressed postero-lateral parts of the diductor scars and the nearest lateral margins of the shell. The teeth project upward and inward, and posterior to the teeth are distinct sockets for articulation with the posterior part of the hinge plates on the brachial valve.

The cardinal process in the brachial valve consists of a very narrow median vertical plate, on each side of which are the bases supporting the crura. The crura project forward from near the inner margins of these bases, and the surface of the latter tends to be distinctly concave toward the cardinal process. The posterior part of the bases articulates with the sockets posterior to the teeth of the pedicel valve, and sockets for the reception of these teeth occur exterior to the bases supporting the crura in the brachial valve. The cardinal process and the adjacent parts of the bases unite anteriorly and connect with the median ridge which extends slightly more than half the length of the valve forward. About 4 or 5 mm. in front of the cardinal process there are more or less distinct lateral branches of the ridge, evidently limiting the anterior from the posterior adductor scars.

From the Buffalo or Maquoketa shales 3 miles east of Frankford, in Pike County, at a small knob on the north side of the pike to Louisiana. Named in honor of Prof. R. R. Rowley of Louisiana, who for many years has investigated the strata of eastern Missouri. Characterized by its large size and by the conspicuous and distant concentric striae.

## 12. *Schizocrania filosa* Hall

In the eastern part of the United States the earliest occurrence of this species is in the Trenton. In Minnesota it occurs as low as the Decorah shales. In Ralls County, Missouri, it is fairly common at several localities near the top of the Plattin limestone; among others, at Conn's Ford, Buford Cave, and along the lower part of Big Creek.

## 13. *Strophomena* cf. *incurvata* Shepard

*Plate XXI, fig. 1, plate XXII, fig. 1*

A single specimen of *Strophomena*, 56 mm. wide along the hinge-line, and 34 mm. long from the beak of the pedicel valve to its margin, was found at locality 3 on Sanders branch, in Ralls County, in the Kimmswick limestone. The concavity of the

pedicel valve is moderate, scarcely exceeding 2 mm.; the convexity of the brachial valve may not have exceeded 7 mm., as far as may be judged from the part remaining. The hinge-area of the pedicel valve is relatively high, equalling at least 3 mm. at the beak. The angle between this cardinal area and the general surface of the pedicel valve is about 15 degrees. The postero-lateral angles equal about 70 degrees. The surface of the valves is covered with radiating striae, 6 or 7 in a width of 2 mm. Every fourth one of these striae tends to be slightly more prominent, this tendency being greater in the brachial valve. The individual specimen here described is associated with numerous specimens of typical *Strophomena incurvata*, and may be only an aberrant form of the latter.

#### 14. *Trematis huronensis* Billings

Outline circular, upper valve moderately convex, the convexity increasing toward the beak. Largest specimen found is 25 mm. in width and 22 mm. long. The surface is ornamented by radiating and concentric striae, the intercepted areas being occupied by small elliptical or more or less quadrangular pits. In some specimens the striae and pits are distinctly perceptible as far as the beak. In these specimens, both the radiating and the concentric striae tend to be narrow, and the intercepted pits tend to be more quadrangular. In other specimens the pits diminish more rapidly in size than the intermediate striae toward the beak, finally appearing as minute circular pits arranged in rows on an area which otherwise is smooth; sometimes the pits disappear altogether before reaching the beak. In a third group of specimens, the concentric striae are considerably narrower than the radiating ones, at least posteriorly, and especially between 5 and 10 mm. from the beak. Anteriorly, in the more mature stages of growth, the specimens are much alike; both the radiating and concentric striae are narrow and the intercepted pits are more or less quadrangular. In the mature stages of growth the number of pits usually varies from 8 to 9 in a width of 2 mm., but in the final stages of growth this number may in-

crease to 10 or 11 in the same distance. Occasional specimens occur in which the number of pits at midlength of the shell, just before reaching the point of intercalation of additional rows of pits, may equal 7, or even 6 in a width of 2 mm. On closer examination, the concentric striae are found to be not strictly continuous. From 4 to 10 pits may form a continuous series in a lateral direction; then there is a slight jog, beyond which there is another continuous series of pits. Only a single specimen was found in which the pits of adjacent concentric rows alternated sufficiently to accord with the description and figure of *Trematis ottawaensis* Billings (Palaeozoic Fossils, 1865, p. 53, fig. 58), from the Trenton limestone at Ottawa, Canada.

The specimens here described occur in the top of the Platin limestone at Conn's Ford, Buford Cave, and at the Yeager locality.

In *Trematis punctostriata* Hall, from the type horizon and locality, in the Saltillo (Trenton) limestone at Clifton, Tennessee, similar features are shown. Posteriorly the pits are small and distant, on an otherwise smooth surface, disappearing before reaching the beak. Anteriorly the pits are separated only by narrow radiating and concentric striae. The number of pits sometimes reaches 8 in a width of 2 mm. near midlength of the shell, increasing to 10 and 12 in the same width along the anterior margin. The concentric arrangement of pits is continuous for distances including 4 to 10 pits, beyond which there is a slight jog, followed by another continuous series of pits. Alternation of pits belonging to adjacent rows, as described in *Trematis ottawaensis*, is confined to only three or four rows in those few cases where it was detected at all.

### 15. *Zygospira deflecta* Hall

*Plate XXII, figs. 5 A, B*

Shells small, scarcely exceeding 3 mm. in length, characterized by a broad and distinct median depression on the brachial valve, its entire width occupied by five radiating plications, the total number of plications on the valve usually equalling 17 to

21. The median part of the pedicel valve, for a width of 4 radiating plications, is distinctly elevated above the rest of the valve. Contrasted with the brachial valve, the pedicel valve is considerably more convex.

Found at the top of the Platin limestone, at Buford Cave, and at the Yeager locality, in Ralls County.

The specimens here described agree fairly well with those figured by Hall (plate XXII, figs. 5 A, B of this bulletin), from the middle Trenton at Martinsburg, New York, as *Atrypa* (= *Zygospira*) *deflecta*. *Zygospira recurvirostris* (Hall), from the same locality and horizon, differs from *Zygospira deflecta* chiefly in the greater convexity of the brachial valve and in the much less conspicuous depression of the median part of this valve. If it be possible to separate *Zygospira recurvirostris* from *Zygospira deflecta* by means of these characteristics, then the Platin limestone specimens come nearer to *Zygospira deflecta*. If these two species prove not distinct, then both must bear the name *Zygospira deflecta*, since the original description of *Zygospira deflecta* precedes that of *Zygospira recurvirostris* in the original description of these species (Paleontology of New York, 1, 1847, p. 140, pl. 33, figs. 4 a, b).

#### 16. *Ctenodonta* of gibberula group.

##### *Plate XXI, fig. 13*

A single left valve of some species of *Ctenodonta* was found near the top of the Platin limestone, about 1 mile northwest of Spalding Springs, near the home of H. W. Ogle. Compared with *Ctenodonta gibberula* Salter (plate II, fig. 13 of this bulletin), the shell is of smaller height, the ventral margin is much less convex, the angle between the hinge areas anterior and posterior to the beak is more divergent, and the entire aspect of the shell is more elongate.

17. *Parallelodus obliqua* Branson*Plate XXI, fig. 14*

A distinct and rather angular umbonal ridge extends from the beak toward the lower posterior angle. The post-umbonal slope is distinctly concave, especially toward the beak. The remainder of the valves, below and anterior to the umbonal ridge, is gently and evenly convex. There is no trace of a mesial depression or sinus. The ventral margin is gently and evenly convex for almost its entire length, rounding more abruptly upward at the two extremities of the shell. The posterior margin of the shell is strongly oblique to the hinge-line, producing a rather narrowly rounded posterior angle. None of the specimens expose the teeth. The general appearance is that of *Modiolopsis*, but the absence of a mesial depression suggests the possibility of identity with *Parallelodus*.

In *Modiolopsis consimilis* Ulrich (plate II, fig. 14, of this bulletin), the ventral margin is nearly straight and the slope between this margin and the umbonal ridge is distinctly flattened.

18. *Cyrtolites ornatus minor* Ulrich and Scofield

Two forms of *Cyrtolites* occur near the top of the Plattin limestone in Ralls County. The largest specimens reach a diameter of fully 18 mm. Those specimens in which the transverse undulations meet the carina almost at a right angle are referred to *Cyrtolites ornatus minor*, while those in which the undulations curve strongly backward are regarded as a variety of *Cyrtolites retrorsus* Ulrich.

19. *Holopea* cf. *concinnula* Ulrich and Scofield*Plate XXI, fig. 7*

A specimen found at the top of the Plattin limestone at Conn's Ford has about the same apical angle as typical *Holopea concinnula* (plate XXII, fig. 7 of this bulletin), but the shell is smaller and the rate of enlargement of the volutions is less rapid.

**20. *Holopea* cf. *parvula* Ulrich***Plate XXI, fig. 6*

A specimen of *Holopea*, 24 mm. in diameter, was found at the top of the Plattin limestone at Conn's Ford. In the elevation of its spire and in the rate of enlargement of its last volution, this specimen resembles the much smaller species *Holopea parvula* (plate XXII, fig. 7, of this bulletin), from the Flanagan member of the Trenton of central Kentucky.

**21. *Hormotoma gracilis angustata* Hall***Plate XXI, fig. 8*

A species of *Hormotoma* is very abundant at every locality in Ralls County, where the top of the Plattin limestone is exposed. The specimens attain a larger size than those ordinarily referred to *Hormotoma gracilis angustata*. Compared with *Hormotoma gracilis subluxa*, from the Auburn of Lincoln County, the volutions are less oblique.

**22. *Hormotoma* (?) *major* Hall**

This species is quite common in the coarsely granular or crystalline McCune limestone in Pike County; if the name McCune be restricted to strata equivalent to the exposures found near McCune station, then the species may be said to characterize this division of the Kimmswick, using the latter term in the broad sense employed by Branson. One of the Pike County specimens was figured by Ulrich in the *Paleontology of Minnesota*, vol. III, pt. 2, 1897, on plate 71 (figs. 5, 6).

**23. *Maclurina manitobensis* Whiteaves**

A single specimen, 50 mm. wide, from the lower part of the *Hormotoma major* or McCune zone, was found on Sanders branch, in Ralls County. It is referred to *Maclurina* on account of the small width of the umbilicus. While the shell is considerably

smaller than mature specimens of *Maclurina manitobensis*, the umbilicus apparently enlarged at the same rate and the keel surrounding this umbilicus rises at about the same angle. In *Maclurina cuneata* the keel rises much more rapidly, and the umbilicus is much narrower.

#### 24. *Maclurites* sp.

A single specimen, 50 mm. wide, from the *Hormotoma major* zone on Sanders branch, is referred to *Maclurites* on account of the relatively wide umbilicus. The specimen may be regarded as a depressed form of *Maclurites bigsbyi* Hall, a Platteville species found in Wisconsin and Minnesota, the shell being more depressed even than figure 7 on plate 75 of the Paleontology of Minnesota, III, part 2, 1897; moreover, the peripheral angle is more acute and the umbilicus exposes fewer volutions. Compared with *Maclurites depressus* Ulrich, from the Platteville of Minnesota, the width of the umbilicus is similar, and the peripheral angle is only moderately greater, but there is no tendency toward concavity on the flattened side of the volutions. Compared with *Maclurites crassa*, Ulrich and Scofield, and its variety *macra*, the umbilicus is much smaller, and the peripheral angle is more acutely rounded.

#### 25. *Conularia heymani* sp. nov.

*Plate XXI, fig. 12, plate XXII, fig. 12*

Only one of the four faces of the shell is exposed and even of this face the lateral margins are not distinctly defined. As far as may be determined from the part exposed, the lateral margins of the one face here described diverge at an angle of about 15 degrees. The median line of the face is occupied by a narrow groove, on each side of which is a slightly raised line, light brown in color. At the smaller end of the specimen the raised lines are about 0.8 mm. apart; 20 mm. farther up they are about 1.25 mm. apart. Beyond this point they can not be measured accurately. The face is crossed transversely by very fine striae which

rise from the lateral margins as far as the slightly raised lines on each side of the median groove, forming an angle of about 75 degrees with these raised lines. Between these lines the transverse lines curve so as to cross the median groove without any interruption or abrupt change of direction.

The number of transverse striae varies from 6 to 9 in a length of 1 mm. near the smaller end of the specimen and also farther up, at midlength. At the larger end, where gerontic conditions appear to have set in, the number of these transverse striae equals 11 to 12 in 1 mm. The transverse striae are very narrow, and their crests are lined with minute granules, numbering from 11 to 17 in a distance of 1 mm. on various parts of the shell. The granules are arranged also in vertical rows. The linear areas between the transverse striae are depressed into broad and rather shallow grooves. Along that margin of the grooves which is nearer the apical end of the shell, very low granules appear, but these granules alternate in position with those on the transverse striae and are visible only under a lens.

The transverse striae cross the pair of slightly raised vertical lines along the median part of the face, as though these lines did not exist. The raised lines appear to be due to features not on the exterior but on the interior of the shell. Along the raised lines the interior of the shell appears to be thickened. In a fossil state this thickened part tends to be preserved better than the adjacent parts. Moreover, during fossilization it tends to be lifted slightly above the adjacent parts. The median groove appears to locate a line of weakness in the shell. In cross-sections the raised lines are seen to be due to the presence of a pair of very short longitudinal septa on the median part of the inner side of each face of the shell.

Found at the top of the Plattin limestone at Conn's Ford, four miles northwest of New London, in Ralls County. Named in honor of A. W. Heyman, in memory of many days spent on geological trips in Ohio and Missouri.

*Conularia heymani* differs from *Conularia granulata* Hall (Pal. New York, 1, 1847, p. 223, pl. 59, figs. 5 a, b), from the Trenton at Middleville, New York, in the absence of distinct vertical striae connecting the vertical rows of granules.

26. *Conularia* sp.

*Plate XXI, fig. 9; plate XXII, fig. 9 A, B*

Half a dozen fragments of some very thin-shelled *Conularia*, rolled up into a more or less tubular form, were found within the living chamber of some Orthoceroid shell. The fragments are enrolled laterally. This is indicated by a narrow dark brown line extending lengthwise down the enrolled fragments. The width of this line is approximately  $\frac{1}{7}$  mm. Along this line the inner side of the shell is supported by a narrow sharp septal ridge, extending about  $\frac{1}{3}$  mm. from the wall of the shell inward. This septal ridge is colored deep brown, and it is the color of this ridge which is seen through the thin wall of the shell itself and which forms the narrow dark brown line as seen on the exterior of the shell. Possibly a minute tube may have run down the interior of this septal ridge, close to the wall of the shell, but this could not be determined beyond all doubt. In order to conform with *Conularia* of the *C. heymani* type, a second brownish line ought to extend down the tubular fragments, parallel to the brownish line actually found, but in none of the fragments was a second line found. However, since in no case a sufficient width of surface was exposed on both sides of the brownish line actually present, it is not possible to determine definitely either the presence or absence of such a second parallel brownish line. Judging from analogy with *Conularia heymani*, it is here assumed that the second brownish line should occur in specimens showing a sufficient width of the original shell wall.

The longest enrolled fragment is 26 mm. long, and the various fragments are enrolled so as to produce the appearance of tubes about 4 or 5 mm. in diameter. All of the so-called tubes are more or less crushed and have their enrolled margins more or less separated.

The surface is ornamented by minute granules, about a 0.05 mm. in diameter. These granules are arranged both in transverse and in vertical rows. In the transverse rows 10 to 13 granules occupy a width of one millimeter, and in the vertical rows usually about 8 granules occupy the same length, although

their number varies from 7 to 9, and 11 occasionally are found. The transverse rows of granules tend to be supported by low transverse wrinkles or striae, but the intermediate grooves never are sharply defined and the wrinkles or striae often are obsolete. In the latter case the granules appear arranged in rectangularly intersecting rows on otherwise nearly smooth surfaces. On some fragments, numerous low parallel wrinkles more or less connect the granules in a diagonal, not in a vertical, direction, somewhat as in *Conularia cayuga* as figured by Hall (Pal. New York, 5, pt. 2, 1879, pl. 34, fig. 5) from the Hamilton group of New York.

From the city quarry, one mile southeast of New London, in the upper part of the Plattin limestone.

### 27. *Hyalithes baconi* Whitfield

*Plate XXI, figs. 10 A, B, 11; plate XXII, figs. 10, 11*

Apical angle 20 degrees. Top of shell 9 mm. in width. Cross-section somewhat triangular, with one side flattened and the opposite side convex, the dorso-ventral diameter at the top of the shell being 2.5 mm. in the shell here described. The small size of this diameter may be due in part to compression. The shell is striated transversely, the direction of these striae being almost directly transverse on the convex side of the shell, while on the flattened side they curve distinctly upward.

In one specimen (fig. 11) the median part of the convex side is slightly more convex than the lateral parts of this side, and is separated from the latter on each side by a slightly concave area. The lateral margins are narrowly rounded. Of the transverse striae 14 occupy a length of 3 mm. at the larger end of the shell, preceded by 15 in the same distance at midlength, increasing still farther in number toward the apical end. The transverse striae are crossed by much finer vertical striae, of which 8 to 10 occur in a width of 1 mm.

*Hyalithes baconi* is fairly common at one horizon near the top of the Plattin limestone, but most specimens do not show the low median elevation on the convex side of the shell and the fine

vertical striae rarely are shown. Possibly most specimens lacking these vertical striae are casts of the interior of the shell.

Found at Buford Cave, 2 miles west of New London, near the top of the Platin limestone.

#### 28. *Hyolithes miseneri* Foerste

Under the name *Conularia miseneri* the writer described a series of specimens from the Whitewater member of the Richmond at Richmond, Indiana (Journal of Cincinnati Soc. Nat. Hist., 22, 1917, p. 42, pl. I, figs. 1 A, B, C). Later it was recognized that the supposed *Conularia* was the convex side of a species of *Hyolithes*, the median part of which was elevated as in the second specimen of *Hyolithes baconi*, described in the preceding lines. The transverse striae are more prominent. Along the median line of the shell they curve slightly downward; laterally they curve more strongly downward as far as the lateral sides of the shell where they begin to curve rapidly upward. From this it is assumed that on the flattened side of the shell the transverse striae curve strongly upward as in other species of *Hyolithes*. The vertical striae are finer but distinct. An almost identical species occurs in the Kimmswick of southern Missouri.

#### 29. *Orthoceras* with vertical color bands.

In a specimen of an unknown species of *Orthoceras* found at the top of the Platin limestone at Conn's Ford, vertical color banding is present. The specimen is 22 mm. in width. The color bands equal or slightly exceed 1 mm. in width and are 1 mm. or slightly less apart. The color banding is a feature characteristic of the inner layers of the shell and is seen best where the surface of the shell has weathered away.

Orthoceroid shells with vertical color bands are known also at other horizons. In the Lorraine formation in the river bed west of Weston, Ontario, vertical color bands occur in an Orthoceroid shell 22 mm. wide, having a siphuncle with nearly spherical segments (*Loxoceras*?). About 8 vertical color bands occur in a width of 5 mm., the width of the color bands and that of the intervals between being about the same.

In a similar species (*Loxoceras* ?), from the Richmond formation at the Clay Cliffs on the eastern shore of Manitoulin Island, the vertical color bands are about 1 mm. in width and are separated by intervals varying from 1 to 2 mm. where the diameter of the shell equals 15 mm.

In *Orthoceras trusitum* Clarke and Ruedemann, from the Guelph at Rochester, New York, specimens occasionally show color banding. In the specimen represented by figure 2 on plate 13 of Memoir 5, New York State Museum, 1903, there are 9 or 10 vertical light brown bands in a width of 3 mm. In the specimen represented by figure 9 the structure usually accompanying color banding is present, but there is no distinctive color here. This structure consists in the space between the color bands being composed of a less dense and more readily weathering material than that forming the color bands.

In all cases of color banding observed by the writer the color banding consisted of various tints of brown.

### 30. *Spyroceras bilineatum* Hall

In typical *Spyroceras bilineatum*, from the Trenton of New York, the coarser vertical striae alternate with finer ones. Conchs of this type occur at the top of the Plattin limestone at Conn's Ford, Buford Cave, and elsewhere in Ralls County. They are accompanied by other specimens in which the vertical striae practically are of uniform size. In one specimen 17 mm. in diameter, these vertical striae number 12 or 13 in a width of 5 mm.

### 31. *Tripteroceras* cf. *planoconvexum* Hall

In the *Hormotoma major* zone  $4\frac{1}{2}$  miles east of Frankford, in Pike County, south of the crossing of the pike to Louisiana across the western branch of Sugar Creek, a species of *Tripteroceras* was found which is identical with the species figured by Clarke from the Prosser limestone at Hader, Minnesota (Pal. Minnesota, III, pt. 2, 1897, pl. 57, fig. 1). Compared with typical *Tripteroceras planoconvexum*, from the vicinity of Beloit, Wisconsin, however, the species here under consideration appears larger, and with a smaller apical angle.

### 32. *Amphilichas cucullus* Meek and Worthen

This species was described from the Kimmswick limestone in Alexander County, Illinois, presumably from the exposure south of Thebes studied by Professor Savage. The same species is common in the second quarter of the so-called Kimmswick limestone of Ralls and Pike Counties, measuring upward from the base. It is one of the most characteristic fossils of this horizon. It is overlaid by the *Hormotoma major* or McCune zone.

### 33. *Bumastus holei* sp. nov.

*Plate XXI, figs. 15 A, B; plate XXII, figs. 15 A, B*

The cast of the lower side of the cranidium is characterized by shallow impressed lunettes, relatively very distant from each other, but rather close to the posterior margin. The length of the cranidium is 25 mm.; its width is 30 mm.; the distance between the impressed lunettes is 18 mm.; the length of the lunettes is 5 mm., and their posterior margin is 5 mm. from the posterior margin of the cranidium. The general convexity of the cranidium from side to side is small.

The associated pygidium is 28 mm. wide, 19 mm. long, and has a convexity corresponding to that of the cranidium. The articulating axial part is 11 or 12 mm. in width, and from this axial part the lateral articulating margins bend back at an angle of about 155 degrees.

Found at locality 3 in the Kimmswick limestone section on Sanders branch. Probably identical with the species figured by Clarke (Pal. Minnesota, III, pt. 2, 1897, p. 722, fig. 36) as *Bumastus orbicaudatus* from the Prosser of Minnesota. The posterior part of the cranidium is not preserved well enough to determine whether or not a median pustule was present here originally named in honor of Prof. A. D. Hole, of Earlham College, Richmond, Indiana.

34. *Bumastus rowleyi* sp. nov.

*Plate XXI, figs. 16 A, B; plate XXII, figs. 16 A, B*

Cranidium 19 mm. long, 21 mm. wide between the palpebral lobes, and 22 mm. wide at the broadest part anterior to the palpebral lobes. The general aspect of the cranidium resembles that of *Bumastus ambiguus* Foerste from the Brassfield limestone of Ohio and Indiana. The cast of the lower side of the cranidium shows impressed lunettes along the dorsal groove. These lunettes are separated by a distance of nearly 10 mm. from each other. They are 3 mm. long and are 4 mm. distant from the posterior margin of the cranidium. Both anterior and posterior to the lunettes the dorsal grooves curve strongly outward. Anterior to the lunettes the dorsal grooves are very faint and terminate in distinct pits at points 15.5 mm. from each other and 11 mm. from the posterior margin of the cranidium. Each pit contains a small central granule. The cranidium is moderately convex except toward the anterior margin where it curves rather abruptly downward.

The associated pygidium is 22 mm. long, 27 mm. wide, and has an anterior elevation of 7 mm. The cast of the lower surface is moderately concave along the doublure, but the upper surface appears to have been slightly convex from the more convex middle parts of the pygidium as far as the posterior margin.

Found at locality 3 in the Kimmswick limestone section along Sanders branch in Ralls County. Compared with *Bumastus indeterminatus* Walcott, from the Leray-Black River of New York (Bull. Mus. Comparative Zoology, 60, 1916, pl. 2), *Bumastus rowleyi* has a longer, narrower cranidium with a different curvature along the anterior part of the dorsal grooves on the cranidium, and the general outline of the pygidium is more triangular, especially posteriorly.

### 35. *Ceraurinus* cf. *trentonensis* Barton

Glabella expanding anteriorly; in one cranidium 12 mm. long, the width of the glabella increases from 8 to almost 10 mm. from the rear toward the front. The general form of the glabella is depressed convex, and is distinctly limited laterally by the relatively shallow dorsal furrow. The first and second pairs of glabellar furrows are distinctly curved; from the dorsal furrow they curve gently forward and then, for a longer distance, backward, the inner ends terminating farther back than their outer ends. The third or posterior pair of glabellar furrows is directed diagonally backward, at an angle of about 55 degrees with the median line of the glabella, joining the occipital furrow at points only 2 mm. distant from each other. The posterior pair of glabellar lobes is distinctly triangular. The first and second pairs of glabellar furrows are narrow and sharply incised. The surface of the glabella is almost smooth or minutely granulated. On the fixed cheeks minute pits may be detected. In general appearance, these cranidia resemble those of *Cheirurus* in which the posterior pair of glabellar furrows is strongly defined as far as its connection with the occipital furrow (Ohio Jour. Sci., 19, 1919, p. 396, pl. 19, fig. 7).

Found at locality 4 on Sanders branch, in the Kimmswick limestone.

In general aspect this species resembles *Ceraurinus scofieldi* (Clarke) from the Platteville at Minneapolis, Minnesota (plate XXII, fig. 19, of this bulletin), but the first and second pairs of glabellar furrows in that species are less distinct and less curved.

### 36. *Ceraurus* cf. *bispinosus* Raymond and Barton

#### *Plate XXI, figs. 18 A, B, C*

The dorsal furrows limiting the sides of the glabella diverge at angles between 22 and 27 degrees in different specimens. All of the glabellar furrows are strongly indented. The eyes are nearly opposite the second pair of glabellar furrows or slightly farther forward. They are about equally distant from the

dorsal furrow and from the furrow following the posterior outline of the fixed cheeks. The ocular ridge is either faint or obsolete; when present, it starts off from the vicinity of the first pair of glabellar furrows. The pustules tend to be more conspicuous anteriorly and also along two diverging lines which extend from near the neck furrow forward toward the frontal lobe in such a manner as to leave a median area in which the pustules are less prominent. The pustules are less prominent also between the two rows of more prominent pustules and the lateral glabellar lobes. On the largest cranidium, 14 mm. long, the most prominent pustules attain a height of 0.5 mm. None are developed into spines. The fixed cheeks are indented with pits, and between these there are a few granules of which several tend to be prominent.

Found at locality 2 along Sanders branch, in the Kimmswick limestone.

From typical *Ceraurus bispinosus* Raymond and Barton (plate II, fig. 23 of this Bulletin), from the Black River formation of the Ottawa area in Canada, the Ralls County specimens differ chiefly in the absence of any pustules sufficiently strong to suggest the presence of spines. From *Ceraurus dentatus* Raymond and Barton, from the Trenton formation of Ontario and New York, they differ in having more rotund glabellar lobes.

### 37. *Ceraurus plattinensis* sp. nov.

*Plate XXI, figs. 18 A, B; plate XXIII, figs. 3 A, B*

Cephalon relatively short. The continuation of the occipital furrow along the posterior part of the fixed cheeks is nearly straight as far as the genal angle; in consequence the angle between the posterior margin of the cephalon and the genal spines appears more abrupt. In other respects the backward curvature of the genal spines resembles that of *Ceraurus dentatus*. The lateral lobes of the glabella are small and rotund, while those of *Ceraurus dentatus* are more nearly transversely oblong. The eyes are set far back, almost opposite the second pair of lateral lobes or slightly farther forward. A faint ocular

ridge passes from the anterior pair of glabellar furrows obliquely backward to the palpebral lobe, or may be entirely absent. The axial lobe of the thorax is relatively broader and the free terminations of the pleural segments spread out farther than in *Ceraurus dentatus*. The strongly developed spines of the pygidium not only curve strongly backward but are even slightly convergent posteriorly. That part of the pygidium which is included between these spines resembles the pygidium of *Ceraurus pleurexanthemus*; no dentate margin is present as in *Ceraurus dentatus*.

From the top of the Plattin limestone at the city quarry a mile southeast of New London, along the lower part of Big Creek, at the Buford Cave, and elsewhere in Ralls County.

### 38. *Endymionia bellatula* Savage

This species was described by Savage (Illinois Acad. Sci., 1917, p. 273, pl. I, fig. 3) from the Thebes sandstone, near Thebes, Illinois. It is cited by him also from Madison Creek, in Calhoun County, Illinois, and from Dover church, in Pike County, Missouri. Prof. R. R. Rowley discovered long ago a locality on the Goodman place,  $\frac{1}{2}$  mile west of Calumet post-office, where this little trilobite occurs in great abundance about 3 or 4 feet above the base of the Buffalo shales.

### 39. *Nileus* sp.

#### *Plate XXIII, fig. 4 A, B*

Eyes very prominent, attaining an elevation of 2.5 mm. in cranidia 15 mm. long, rising rather abruptly above the general surface of the cephalon, and limited on the inner side by broad though shallow depressions. In specimens whose palpebral lobes are 10 mm. apart the shallow depressions along their inner sides have their deepest parts about 6 mm. apart. The median parts of the cranidia, between these shallow depressions, may be regarded as the poorly defined glabella which broadens anteriorly and merges into the general curvature of the cranidium.

Posteriorly a few specimens show traces of a prolongation of the shallow depressions backward in the form of almost obsolete dorsal furrows. The anterior part of the cranidium curves downward without any indication of a marginal concave curvature of the cephalon. Anteriorly the facial sutures meet at an obtuse angle; nevertheless this angle is sufficient to indicate that the facial sutures could not have been practically marginal.

Pygidium convex as far as the posterior margin. Axial lobe almost or entirely obsolete. Antero-lateral margins curved abruptly downward along a distinctly angular ridge. Between this ridge and the antero-lateral angle, the slope is distinctly concave. Posteriorly, the margin of the pygidium is slightly angular rather than evenly convex.

From the limestone immediately beneath the Buffalo or Maquoketa shales at the W. H. Benham locality, 3 miles south of Frankford, in Pike County. This limestone rests on the top of the typical Kimmswick, and is regarded as also of Mohawkian age.

Compared with *Nileus vigilans* Meek and Worthen, from the lower Maquoketa of the upper Mississippi valley, the Trenton form here described, according to E. O. Ulrich (in a letter), has much less prominent eyes, larger palpebral lobes; the eyes situated farther from the anterior edge of the cephalon; the anterior outline of the cephalon is more uniformly rounded; the fixed cheeks are shorter; the front slope of the cranidium is less sharply deflected; the antero-lateral angles of the cranidium are less rounded; and the corresponding parts of the free cheeks, where they bend around the front of the cranidium, are narrower.

#### 40. *Proetus undulostriatus* Hall.

A small cranidium, 3 mm. in length, was found at locality 2 along Sanders Creek, in Ralls County. It differs from typical *Proetus undulostriatus* from the Trenton (Snake Hill) of New York, chiefly in the greater distance between the anterior margin of the glabella and the narrow anterior border of the cephalon. Moreover, the intervening part is distinctly convex, and at the

line of contact with the glabella it is distinctly indented. In these particulars the Ralls County specimen agrees better with the minute specimen of *Proetus* figured by Ruedemann (Bull. New York St. Mus., No. 49, 1901, p. 62, pl. 4, figs. 5, 6, 7), from the Trenton (Rysedorph) of New York.

#### 41. *Pterygometopus* cf. *lincolnensis* Branson

*Plate XXI, fig. 19*

*Pterygometopus lincolnensis* Branson differs from *Pterygometopus eboreus* (plate II, fig. 20, of this Bulletin), from the Trenton of New York, in the absence of genal spines; the third pair of lateral glabellar lobes is not confluent with the second; no tubercle occurs on the occipital ring; the frontal lobe of the glabella is shorter and broader; the eyes are larger; and the fixed cheeks are smaller. At the top of the Plattin limestone, at the Buford Cave, specimens resembling *Pterygometopus lincolnensis* occur, but these have distinct genal spines. An examination of the types of Branson's species suggests that better preserved specimens of the latter may also have genal spines.

Another form similar to *Pterygometopus lincolnensis*, found in the Tyrone member of the Black River formation at High Bridge, in central Kentucky, was described by me recently as *Pterygometopus confluens* Foerste (Ohio Jour. Sci., 19, 1919, p. 396, pl. 19, fig. 19). It is refigured in this bulletin as figure 22 on plate II. It differs from the other known forms in the flatness of the cranium, including all of its lobes.

In *Pterygometopus intermedius* (Walcott), from the Black River formation of the upper Mississippi Valley, all of the lateral glabellar lobes are free (plate II, fig. 21 of this bulletin).

#### 42. *Remopleurides missouriensis* sp. nov.

*Plate XXI, fig. 17; plate XXII, figs. 17 A, B*

In the best preserved cranium, the width of the glabella, at midlength of the palpebral lobes, is 7.2 mm., and each of the palpebral lobes is slightly over 0.2 mm. in width. The length of the glabella is 7 mm., and the neck segment adds 1 mm. in

estimating the length of the cranium. The facial suture curves abruptly downward, 5 mm. from the neck furrow, for a distance of 1.2 mm., thus limiting the frontal lobe of the glabella laterally with nearly parallel parts of the facial suture. Here the width of the frontal lobe is slightly over 5 mm. Viewed from above, the anterior outline of the frontal lobe, as far back as the anterior margin of the palpebral lobes, appears rather evenly convex. Viewed from in front, or from the side, the anterior part of the cranium rises abruptly for a height of 1 mm., then curves rapidly backward, attaining its maximum height of 2 mm. about on line with the anterior pair of glabellar furrows. Except along the frontal lobe, the glabella is only moderately convex, especially posteriorly. The palpebral lobes are 4.5 mm. in length, and extend as far back as the neck furrow. The posterior margin of the glabella is distinctly defined by an abrupt though very slight lowering of that part of the glabella forming the neck segment. The median tubercle on the neck segment is almost invisible.

There are three pairs of glabellar furrows. Of these the middle pair is the longest. They are 2 mm. in length, and are separated by a distance of 2 mm. Both furrows are slightly curved, with their convex sides facing forward. Their outer termination is slightly in advance of the inner one. The anterior pair of glabellar furrows are about 1 mm. long, and are separated by a distance of 2 mm. They also are slightly convex toward the front. The posterior pair of glabellar furrows are slightly over 1 mm. in length; they are separated by a distance of almost 3 mm., and they are more convexly curved than either of the other two pairs of furrows. All three pairs of furrows consist of smooth lines, scarcely 0.1 mm. in width, in their present condition appearing as slightly darker lines contrasted with the whiter adjoining parts of the cranium.

The surface of the cranium is marked by minute granules which become larger toward the margin of the cranium. Under a microscope the granules are seen to be elongated transversely. Anteriorly, their upper surface slopes gradually downward. Posteriorly, the slope is more or less abrupt, often being

limited by a more or less lunate outline which becomes conspicuous on cross-illumination.

The hypostoma closely resembles that of *Remopleurides striatulus* Walcott (Cincinnati Quarterly Journal of Science, II, 1875, p. 347) in general form, and is 6 mm. in length.

From localities 2 and 4 in the Sanders Branch section, in the Kimmswick limestone.

In *Remopleurides striatulus* Walcott (plate II, figs. 18 A, B, C, of this Bulletin), from the Trenton of New York, the smooth lines indicating the glabellar furrows are indistinct, those corresponding to the anterior and posterior pairs being extremely obscure. The general curvature of the glabella is very moderate except at its anterior margin, where the frontal lobe curves more strongly downward.

Compared with *Remopleurides striatulus*, the Ralls County specimens have much more distinct indications of the glabellar furrows; the frontal lobe curves downward more strongly and for a greater distance; and the general aspect of the glabella is somewhat narrower and less flattened.

In *Remopleurides linguatus* Ruedemann, from the basal Trenton (Rysedorph) of New York, the anterior extension of the frontal lobe is much narrower and more prolonged.

In *Remopleurides tumidus* Ruedemann, from the same horizon and locality, the glabella is relatively broader, the anterior extension of the frontal lobe is shorter, and it is bounded laterally by more converging facial sutures; moreover, the convexity of the cranium from front to rear is greater.

#### 43. *Bathyrus spiniger* Hall

##### *Plate XXII, fig. 20*

Cranidium with posterior margin of neck ring dentate on each side of the median spine. Those parts of the cranium which are immediately posterior to the palpebral lobes are indistinctly preserved. From the top of the Plattin limestone, in the city quarry, 1 mile southeast of New London, in Ralls county.

## APPENDIX: SILURIAN SPECIES

44. *Platymerella manniensis* Foerste*Plate XXIII, figs. 5 A-H*

*Platymerella manniensis* Foerste, originally described from the Brassfield of western Tennessee, and later found by Savage in the basal part of the Sexton Creek equivalent of the Brassfield in northeastern Missouri and adjacent Illinois, and also in the northeastern corner of Illinois, has been found recently in the basal layers of the Brassfield at Lawshe, in Adams County, Ohio. The Lawshe specimens are of special interest on account of exposing the interior of the valves. Viewed from the exterior, the dissociated valves are so closely similar that it is difficult to distinguish the pedicel valves from the brachial ones. When attached to each other, the umbo of the pedicel valve rises farther above the hinge-line, so that the beak is more curved.

Pedicel valve (figs. 5 A, B, C, D) with an oval or rhomboid spondylium, about 5 mm. long, strongly divergent from the surface of the interior of the valve, and supported by a thin, tall median septum which disappears within 5 mm. from the anterior margin of the spondylium. Pitted ovarian markings are present on the posterior part of the interior.

Brachial valve (figs. 5 E, F, G) with two short crural plates, about 3 or 4 mm. in length, converging along the median line and forming a cruralium resting directly upon the bottom of the interior of the valve. The crural prolongations of the anterior margin of the crural plates rarely are preserved. Along the median line of the shell the anterior part of the cruralium is prolonged into a low and narrow septal line. In one specimen (fig. 5 H) the crural plates rest directly upon the bottom of the interior of the valve, and are prolonged anteriorly into two sharp parallel ridges, about a millimeter in height, 3 or 4 mm. long, and slightly over 2 mm. apart.

The genus *Platymerella* is characterized by its flattened, elongate form; the absence of a cardinal area; the delthyrium is concealed entirely by the contact of the beaks of the two

valves with each other; both the spondylia and cruralia are short, the former being supported on a high median septum and the latter being sessile along the median line on bottom of the interior of the valve. The exterior of the pedicel valve shows no tendency toward a median depression or groove. The genus is regarded as related most nearly to *Pentamerella*, a Devonian genus. In *Pentamerella* the shell is short, deep, and galeatiform, the spondylium is not supported by a long septum, there is a tendency toward a narrow sinus on the exterior of the pedicel valve, the delthyrium is exposed, there is a pseudo-cardinal area, and the anterior septal extensions of the crural plates unite at the base so as to form a cruralium resting on the inner surface of the brachial valve.

## PLATE XXI

Fig. 1. *Strophomena* cf. *incurvata*. Pedicel valve. Locality 3 on Sanders branch, in Kimmswick limestone.

Figs. 2, 3. *Rafinesquina deltoidea*. Pedicel valves. Locality 4 on Sanders branch, in Kimmswick limestone.

Fig. 4. *Parastrophia hemiplicata* var. Pedicel valve. Locality 4 on Sanders branch, in Kimmswick limestone.

Fig. 5. *Platystrophia shepardi*. Brachial valve. Locality 3 on Sanders branch, in Kimmswick limestone.

Fig. 6. *Holopea* cf. *parvula*. From Conn's Ford, at top of Platin limestone.

Fig. 7. *Holopea concinnula*. From Conn's Ford, at top of Platin limestone.

Fig. 8. *Hormotoma gracilis angustata*. From Conn's Ford, at top of Platin limestone.

Fig. 9. *Conularia* sp. Enrolled fragments. From city quarry, 1 mile south-east of New London, near top of Platin limestone.

Fig. 10. *Hyalithes baconi*. *A*, convex side of fragment, with lower end restored; from Buford cave. *B*, flattened side of second specimen, from J. H. Smith farm. Both from top of Platin limestone.

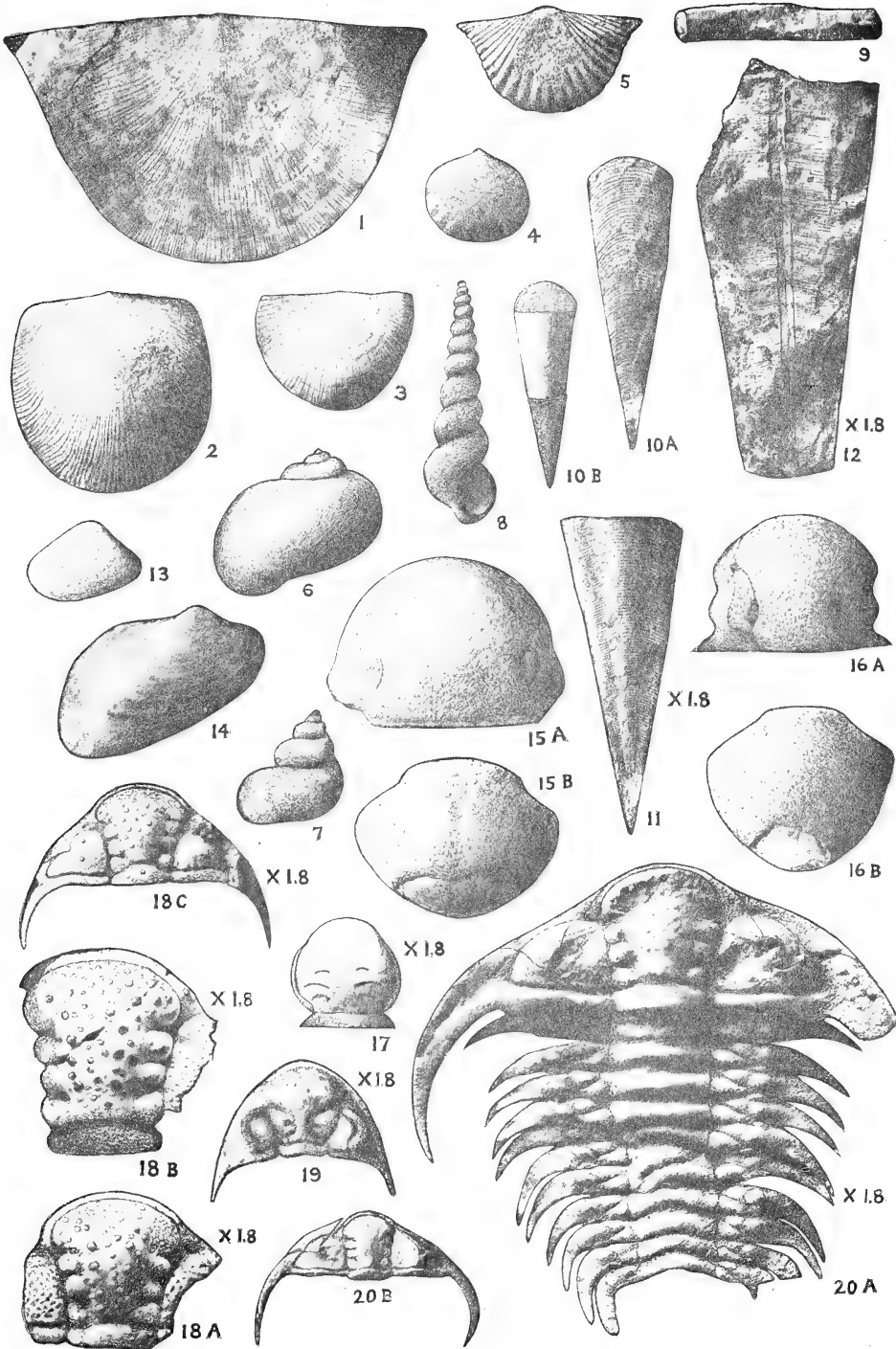
Fig. 11. *Hyalithes baconi*. Convex side. From Buford Cave, at top of Platin limestone.

Fig. 12. *Conularia plattinensis*. Fragment apparently exposing almost all of one face. From Conn's Ford, at top of Platin limestone.

Fig. 13. *Ctenodonta* sp. (*gibberula* group). Left valve. From 1 mile north-west of Spalding Springs, near home of H. W. Ogle, at top of Platin limestone.

Fig. 14. *Parallelodus obliquus*. Right valve. From Conn's Ford, at top of Platin limestone.

Fig. 15. *Bumastus holei*. *A*, cranidium; *B*, pygidium. From locality 3 on Sanders branch, in Kimmswick limestone.



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Fig. 16. *Bumastus rowleyi*. *A*, cranidium; left side restored; *B*, pygidium. Locality 3 on Sanders branch, in Kimmswick limestone.

Fig. 17. *Remopleurides missouriensis*. Cranidium, with the smooth lines representing the glabellar furrows darkened. Locality 2 on Sanders branch, in Kimmswick limestone.

Fig. 18. *Ceraurus cf. bispinosus*. *A*, *B*, fragments of cranidia with traces of ocular ridge on right side. *C*, cephalon lacking the free cheeks, genal spine on right side restored. Locality 2 on Sanders branch, in Kimmswick limestone.

Fig. 19. *Pterygometopus cf. lincolnsis*. Cephalon, left side and part of margin restored. From Buford Cave, at top of Plattin limestone.

Fig. 20. *Ceraurus plattinensis*. *A*, an almost entire individual, proximal parts of genal spines widened by crushing; from city quarry, one mile southeast of New London. *B*, Cephalon, from Harvey farm on lower Big Creek, at top of Plattin limestone.

Additional figures of some of the specimens illustrated on this plate appear on the following plate.

## PLATE XXII

Fig. 1. *Strophomena incurvata*. Curvature of median line of valves of specimen figured on preceding plate; with pedicel valve on right.

Figs. 2, 3. *Rafinesquina deltoidea*. Outlines of specimens figured on preceding plate, viewed from the side.

Fig. 4. *Parastrophia hemiplicata* var. *A*, second specimen, from same locality as that figured on preceding plate, weathered so as to show spondylium formed by dental lamellae, supported by median septum anteriorly.

Fig. 5. *Zygospira deflecta*. *A*, pedicel valve; *B*, anterior view; from the Trenton of Lewis County, New York. Copied from figures 4 *a*, *b*, on plate 33, of Pal. New York, 1, 1847.

Fig. 6. *Holopea parvula*. From Flanagan member, near top of Trenton, near Burgin, in central Kentucky. Copied from figure 19, on plate 79, of Pal. Minnesota, III, pt. 2, 1897.

Fig. 7. *Holopea concinnula*. From the Platteville near Beloit, Wisconsin. Copied from figure 6 on plate 79 of Pal. Minnesota, III, pt. 2, 1897.

Fig. 8. *Hormotoma gracilis angustata*. From top of Decorah formation at Cannon Falls, Minnesota. Copied from figure 32 on plate 70 of Pal. Minnesota III, pt. 2, 1897.

Fig. 9. *Conularia* sp. *A*, granular surface, magnified 12 diameters, to show arrangement of granules in transverse and in longitudinal rows. *B*, several cross-sections of the enrolled fragments. From same series as the specimen represented by figure 9 on the preceding plate.

Fig. 10. *Hyalolithes baconi*. Cross-section of specimen used for figure 10 *B*, on preceding plate.

Fig. 11. *Hyalolithes baconi*. Cross-section of specimen used for figure 11 on preceding plate.

Fig. 12. *Conularia plattinensis*. Imaginary cross-section of specimen similar to that used for figure 12 on preceding plate, indicating position of the pair of vertical ridges along the median part of the faces, supported interiorly by short septal striations.

Fig. 13. *Ctenodonta gibberula*. Mould of interior of left valve, from the Platteville at Minneapolis, Minnesota. Copied from figure 37 on plate 42 of Pal. of Minnesota, III, pt. 2, 1897.

Fig. 14. *Modiolopsis consimilis*. Right valve, from the Stones river group at Murfreesboro, Tennessee. Copied from figure 17 on plate 42 of Pal. Minnesota, III, pt. 2, 1897.

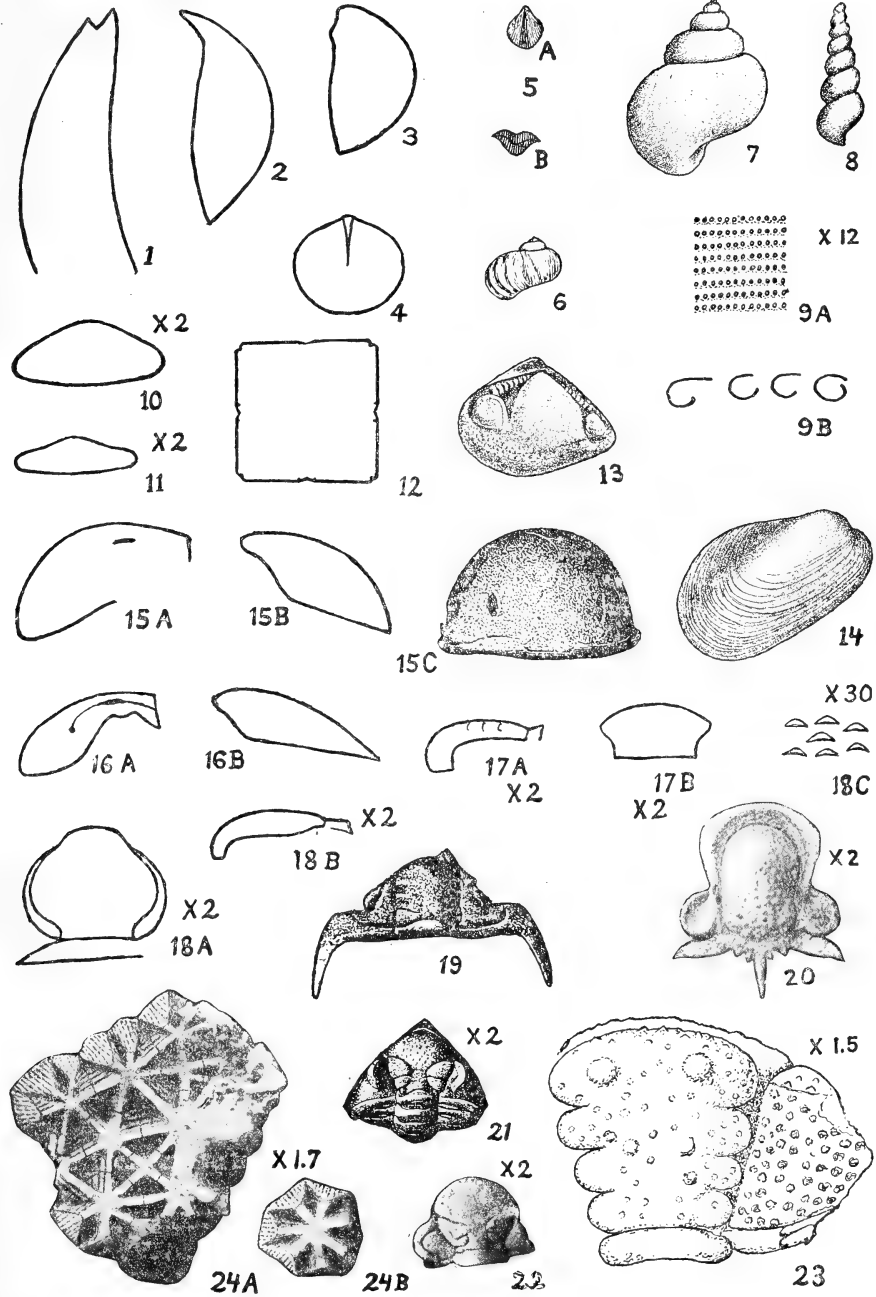


Fig. 15. *Bumastus cf. billingsi*. *A, B*, outlines of cranium and pygidium figured on preceding plate, viewed from the side. *C*, specimen figured by Clarke as *Bumastus orbicaudatus*; copied from figure 36 on page 722, of Pal. Minnesota, III, pt. 2, 1897.

Fig. 16. *Bumastus rowleyi*. *A, B*, outlines of cranium and pygidium figured on preceding plate, viewed from the side.

Fig. 17. *Remopleurides missouriensis*. *A*, outline of specimen figured on preceding plate, viewed from the side; *B*, viewed from the front, showing the frontal lobe.

Fig. 18. *Remopleurides striatulus*. *A*, specimen from type locality, in U. S. Nat. Mus., viewed from above; *B*, lateral view of same; *C*, short nodose striations, magnified 30 diameters. From Trenton limestone at Trenton Falls, New York.

Fig. 19. *Ceraurus scofieldi*. Cranium, from Platteville limestone at Minneapolis, Minnesota. Copied from figure 55 on page 735 of Pal. Minnesota, III, pt. 2, 1897.

Fig. 20. *Bathyurus spiniger*. *A* cranium, with fixed cheeks posterior to palpebral lobes indistinctly defined. From city quarry, 1 mile southeast of New London, near top of Platin limestone.

Fig. 21. *Pterygomotopus intermedius*. Cephalic view of enrolled specimen; species occurs both in Platteville and Decorah of Minnesota. Copied from figure 45 on page 728 of Pal. Minnesota, III, pt. 2, 1897.

Fig. 22. *Pterygomotopus confluens*. Cranium from Tyrone member of strata exposed at High Bridge, Kentucky. Showing confluence of outer parts of first and second pairs of glabellar lobes, as in *Pterygomotopus eboraceus* and *Pt. lincolniensis*.

Fig. 23. *Ceraurus bispinosus*. Fragment of cranium, from Black River limestone at Tetreauville, province of Quebec. Copied from figure 4 on plate I of Bulletin of Museum of Comparative Zoology, 54, no. 20, 1913.

Fig. 24. *Comarocystites shumardi*. *A*, fragment of theca adjoining anal aperture, viewed from interior. *B*, a single thecal plate viewed from interior. From top of quarry in Kimmswick limestone,  $\frac{1}{2}$  mile northwest of West Kimmswick, Missouri.

#### PLATE XXIII

Fig. 1. *Mcewanella raymondi*. Brachial valve. From Mincke, St. Louis County, Missouri; in Kimmswick limestone.

Fig. 2. *Rhynchotrema rowleyi*. *A, B*, pedicel valves, exteriors. *C*, pedicel valve, interior. *D*, brachial valve, interior. From small knob, 3 miles east of Frankford, on road to Louisiana; in Buffalo or Maquoketa shales.

Fig. 3. *Ceraurus plattinensis*. *A*, pygidium. *B*, hypostoma. From Buford Cave, 2 miles west of New London; at top of Platin limestone.

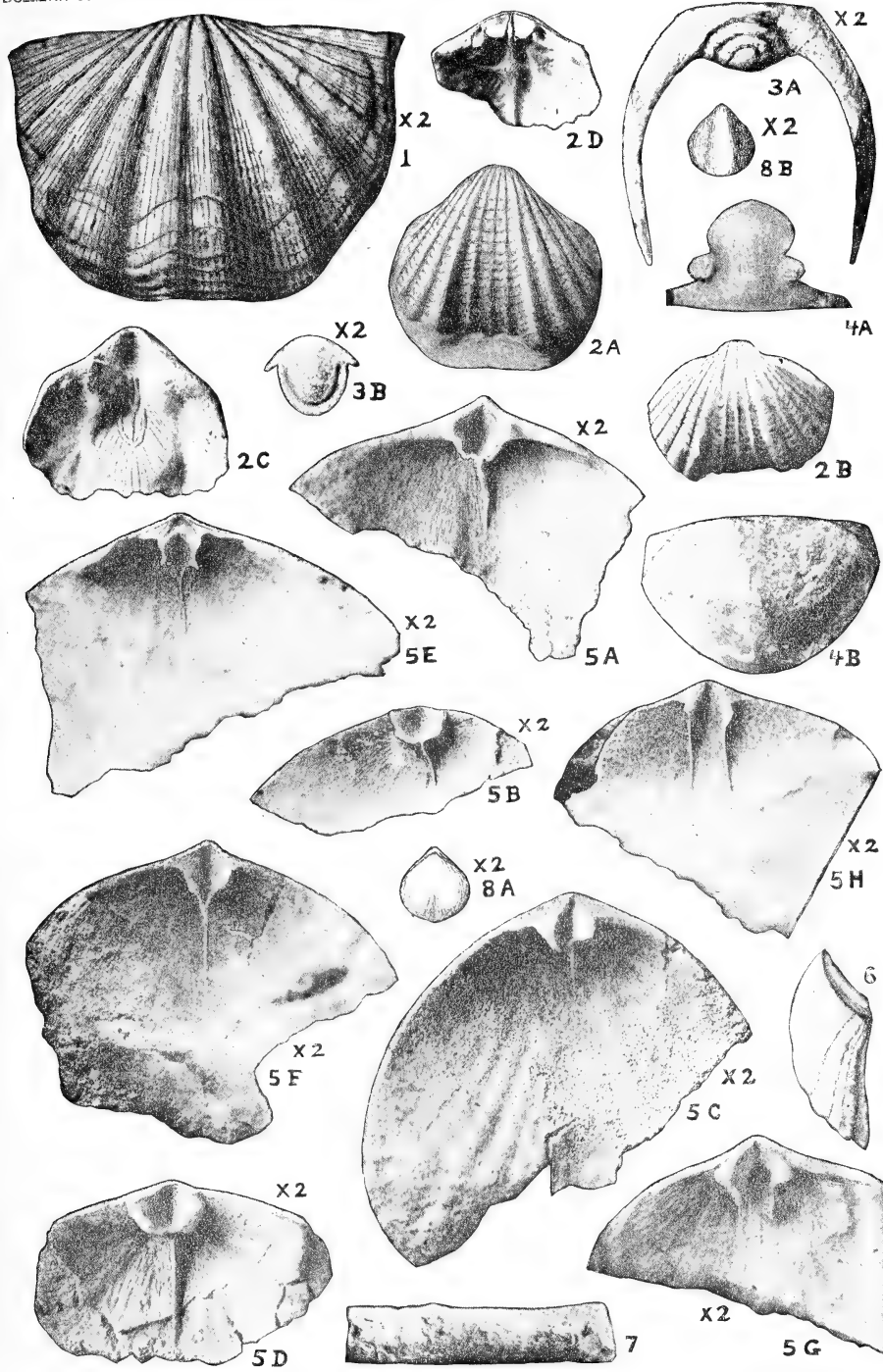
Fig. 4. *Nileus* sp. *A*, cranium. *B*, pygidium. From a coarse limestone layer immediately beneath the Buffalo or Maquoketa shales, east of the home of W. H. Benham, 3 miles south of Frankford, on a branch of Peno creek.

Fig. 5. *Platymarella manniensis*. *A-D*, pedicel valves, interiors. *E-H*, brachial valves. From Lawshe, Adams County, Ohio. In basal part of Brassfield formation.

Fig. 6. *Clitambonites cf. diversus*. Pedicel valve, lateral view. From Mincke, in St. Louis County, Missouri; in Kimmswick limestone.

Fig. 7. *Beatricea gracilis* Ulrich. Lateral view of fragment of a much longer stem. From quarry east of pike, a short distance north of Auburn, Missouri; in Auburn limestone.

Fig. 8. *Zygospira nicolleti*. *A*, brachial valve. *B*, pedicel valve. From Buford Cave, 2 miles west of New London, at top of Platin limestone.



FOERSTE: BRASSFIELD, MAQUOKETA, KIMMSWICK AND PLATTIN FOSSILS



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Granville, Ohio

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## EDUCATION FOR SCHOLARSHIP<sup>1</sup>

WILLIAM E. CASTLE

James Bryce, that observing and benevolent and wise Englishman, who spent so many years among us as his country's representative at Washington, and who knows us Americans better than we know ourselves, —Bryce has said that the finest thing in American life is our universities. Here our youth turn aside from the work-a-day world in which they grow up, and to which they will presently return, and for a few years while the mind is vigorous and keen come in daily contact with the best products of man's thinking in all the ages that have gone before. If with such contacts our young men and young women do not themselves learn to think correctly and act wisely, it will not be for lack of opportunity to learn but rather because of failure to appreciate properly and to seize effectively the opportunities offered. That our young people do, with few exceptions, value the opportunities of college life highly is shown by the practical unanimity with which in later life they send their own children to college, and when the college needs money to carry on and enlarge its work, they give money freely in its support, more freely than for any other object you can mention.

Why is it, do you suppose, that we value so highly our college days and wish our children to enjoy college days too? I can mention one reason; it is because in college days, we have opportunity to think about and to discuss general questions, aside from their immediate application to our own personal interest. This makes for clear thinking and sound judgment. We do not allow a judge to sit on a case in which he is personally interested. We think it is difficult for him to judge impartially under such circumstances. Similarly we want our young people to be

<sup>1</sup> An address delivered at the Ninetieth Annual Commencement Exercises of Denison University, June 15, 1921.

free from bias when they are weighing general questions and are adopting general principles which are to serve as constitutions of personal conduct for their daily lives. This is the essence of that "academic atmosphere" which surrounds a university, and which means freedom from bias, and which is sometimes condemned by men who call themselves "practical," just because it *does* mean freedom from bias and does not permit of the decision of large questions on the basis of small, local and selfish interests.

The academic atmosphere is friendly to thought, to inquiry, to the extension of every field of knowledge, without pausing to inquire whether it is immediately useful.

Benjamin Franklin, a self-educated man of genius, founded the oldest of the learned societies of America, whose official title is The American Philosophical Society held at Philadelphia for the Promotion of Useful Knowledge. Franklin, apparently, thought to rule out all knowledge that was not useful, as those do today who would admit to educational programs only vocational studies. But if Franklin or his successors ever seriously attempted to exclude from consideration in his Society any branch of knowledge on the ground that it was not useful, they long ago abandoned the attempt. The two-day program of the Annual Meeting of the Society which I sat through two years ago in the Society's little old building on historic Independence Square, with Ben. Franklin's crude apparatus in glass cases round the wall and outside the noise of a great commercial city roaring by,—that program covered every subject under the sun, from the folk lore of primitive savage tribes and the philosophy of primitive Christianity, to the best methods of preventing erosion on sea-beaches, and the ultimate constitution of atoms.

No man, however wise, can tell us what knowledge is useful and what knowledge is not or is not likely to be useful. Great industrial establishments are coming to appreciate this fact. They recognize the potential value of fundamental truth, however abstruse. For example the General Electric Company employs eminent physicists drawn away by high salaries from the laboratories of our universities, for what purpose? To plan electrical machines or to devise new uses for electricity? No, to study the

composition of the atoms of which all material objects are composed; hypothetical structures, infinitely small, which no man has ever seen. Why is the General Electric Co. interested in the pursuit of an investigation so abstruse as this? Because the man who can tell us what holds the atoms together, will place at our disposal unlimited power. If we ever learn how to utilize atomic energy, we can discontinue the mining of coal and the pumping of oil. The General Electric Co. is willing to risk a little of its surplus in the venture of trying to hasten that day.

Since it is impossible to say what knowledge is useful, the university properly takes all knowledge as its field, and seeks to increase and to diffuse that knowledge. It seeks to place on its faculty men or women who have contributed in some way to the increase of knowledge, believing that such men and women are calculated to inspire in their pupils a zeal for knowledge and a desire to increase knowledge, or else the university chooses for its faculty those who have shown an unusual aptitude for *imparting* knowledge, because the ability to acquire and to impart knowledge are not always found in the same individual, indeed such a happy combination is rather unusual. For this reason university faculties should include both types of men, teachers and investigators, but the fundamental or introductory courses should always be in charge of those "apt to teach," filled with enthusiasm for knowledge and bursting with a desire to impart it. Such only are born teachers. Unless the student, early in his course, acquires a taste for learning and desires to go on learning the rest of his life, he will never make a *scholar*, which means that he will not get the most out of college life. For after all, the *serious business of college life is scholarship*. You would never know this from reading the newspapers. You would suppose that a university was great in proportion to the strength of its athletic teams, but that is not so. The effectiveness of gun fire is measured not by the amount of noise made but by the proportion of hits. Scholarly achievements in university life are hits, athletics mostly noise.

Scholarship does not consist in the mere accumulation of facts, but in the ability to take a body of facts and draw sound conclu-

sions from them. Edison reports that the college men did not stand particularly high in the examinations which he set to test possession of a mass of miscellaneous information. By implication the colleges are to blame. But the colleges are not concerned with imparting miscellaneous information to their students. If that is what is wanted, the student would do well to stay at home and study the World Almanac. The colleges are concerned primarily in teaching young people how to think. Some one has said that it makes no difference what subject you study provided you study it in the right way, so as to master it, so as to make it your own, so that if all the books on a subject were destroyed, all the facts and statistics about it were forgotten, you could sit down and block out the *principles* on which the subject could be built anew. *That* is scholarship.

While it is true, I believe, that all branches of knowledge have educational value, it is not true that all have equal educational value, or are equally serviceable in developing all types of minds. Some studies are more useful as instruments of education at one stage of mental development or to one type of mind than to another. Experience shows that language study is one of the earliest available and most generally useful instruments of education. Students of mankind tell us that in the development of the race growth in thought and in its vehicle, language, went hand in hand, each process stimulating the other, thought being incapable of expression or even of formulation except as suitable language was found for it. What was true of the race is true in the development of the individual. Language is indispensable to thought but the amount of language study which can profitably be undertaken in individual cases varies greatly. Some find the mother tongue all they are able to master, and it is indeed adequate, if the other mental powers are well developed, to place at one's disposal in translation or otherwise the wisdom of all the ages. A boy who is dull at language, should not be kept at language study all his school days, until his interest is killed in studies of every sort, but should be allowed to go on in other fields, as he shows capacity to do so.

I speak of language study, by way of illustration merely. The principle stated will apply equally well to any other subject. All minds are not alike and so we should not have one stereotyped course of study for all. We might apply to education what Bacon said concerning food, "Now good digestion waits on appetite and health on both." The educational food must be appetizing if the student is to digest it and grow mentally by reason of it. While the tastes and aptitudes of the student should be influential in determining the choice of his studies, they should not be the exclusive consideration, any more than we should feed our children exclusively on candy just because they like it. We feed them what we think is good for them and try to present it to them in an appetizing form. That seems to be the essence of rational child feeding.

Pope's dictum that "The proper study of mankind is man" is often quoted by those who favor the humanities in educational programs: language, literature, history, philosophy, and the like; and it must be admitted that such studies have the widest appeal, since they embody an epitome of all that man has thought, said or done since he emerged from savagery, and thus involve the rudiments of civilization.

But the story of man before the beginning of the historical period is a much longer one than that which deals with the comparatively brief and modern civilized period. Yet it is a harder task to decipher that story. It has to be done in the light of archeology and anthropology, which in turn lean strongly on zoölogy and botany, and they on geology, chemistry, physics, and astronomy, and all of them on mathematics. So there is no subject which is not important to a proper understanding of man and his place in nature. The task is too great for any one mind to undertake to master them all and so scholars have to divide the field among them and each one work in his own corner. Only when the mind is young and fresh and receptive is it given to anyone to make a general survey of the whole field of knowledge, and select the small portion which with proper industry he may hope to make his own. These are the glorious days of youth, college days, when under the guidance of inspiring teach-

ers, we are permitted to go up into a high mountain and look over into the promised land of knowledge spread out before us like a map. For some of us that vision ends with college days, but the memory of it remains and makes us wish that our children may have it too, and that is why we send our sons and daughters to college.

When I was a student in college two rival theories concerning the origin and nature of man were placed before us. Part of the faculty favored one theory, part the other, so we students had to do some thinking of our own if we reached any conclusions, and to think for himself is not a bad training for the student.

According to one theory, man was not *of* the earth though he was *on* the earth. Heaven was his home, here he was a stranger, a sojourner, a wayfarer, defiled by contact with things earthly, trying to divest himself as rapidly as possible of the polluting medium in order that he might again reach a pure state. He had nothing to hope for in life except to make a safe escape from it.

According to the other theory man was a product of the earth itself, the highest stage at present in a process of orderly development. Indications of what some of the earlier stages were, through which he had passed, were seen in the lower forms of life, animal or plant, or even in the rocks, which as they decay form soil in which plants grow, on which in turn animals feed. On this theory, man was no stranger here on earth but a part of a creative process still in progress.

Some of us students adopted one theory, some the other, and I suppose today we hold much the same views that we adopted then. People do their best thinking, as a rule, when they are young, make up their minds then on fundamental questions and rarely change them afterward. But fortunately these same fundamental questions come up for study anew in every generation and are never settled. Every student for himself can apply to them the try-square of truth.

My own interest in this question of the nature and origin of man led me into the study of biology and ultimately into that of heredity, at a time when great discoveries were being made in this field. It is safe to say that since 1900 more has been

learned about heredity than had been discovered in all the preceding centuries. This subject has been studied chiefly in the case of plants and the lower animals, and much of practical value has been learned concerning it. We are now able, through a knowledge of some of the laws of heredity, to breed animals and plants better adapted to agricultural needs than any which existed before. We know how to produce any desired combination of characters in our animals and plants, provided we can first discover the characters which it is desired to combine. We know, too, that these same laws which govern heredity in plants and animals govern heredity also in man. Whatever theory we hold about the *past* of man, about his origin, we cannot fail to see that this knowledge of heredity places in the hands of the human race the possibility of controlling in a measure its own future. So far as the laws of heredity are concerned the human race could be moulded to an improved type as easily as our cultivated plants and domestic animals can be. Our knowledge of human heredity is yet too incomplete to warrant the suggestion of specific measures, except in a very tentative way, but it is time that we began thinking about the subject, and placing it before the minds of our students as a subject for investigation.

Common observation tells us that some races of mankind are better endowed physically, mentally or morally, than others. The same is true of families in a community. We have in America about every racial stock in existence poured into the melting pot, and we have a good opportunity to compare them and estimate their racial values. Shall we let them all come without restraint or shall we make a selection of the ingredients? A student of heredity who desired to improve the human stock on this continent would have no hesitation in favoring selective restriction. Even within our own borders, there occur human strains of low mentality, or loose morals, usually both, that the community would be better off without. The animal husbandman sees to it that inferior strains do not increase. Can human society do the same?

Then there are good human strains, no less than bad ones, families which generation after generation produce men of good

physique and sound minds or skilled hands. In their production the elements of environment, education and family tradition must not be disregarded, but after all due allowance is made for these factors, it is still true that heredity is an important element in producing good family strains no less than bad ones.

Can a way be found, without undue interference with personal liberty, to increase the good human strains and to decrease the poor ones?

Finally there is another problem which the human race must face in the light of biology as well as of history, that of population. There is a limit to the number of people who can live comfortably on a limited amount of land. It is true that the world supports much larger populations now than it did a few centuries ago and supports them in much greater comfort, due chiefly to advances in applied science, but still many countries are overcrowded. Overcrowding leads in time to poverty, famine, and war. Would not an intelligent control of the increase of population act as a deterrent to war and its attendant miseries? Our college graduates will not solve the problem by limiting the size of their own families. They have gone too far already in that direction and are not now replacing themselves in the population. Roosevelt pointed out very clearly the consequences of this policy, which he denounced as "race suicide." He did not wish to see our children cheated of their birthright, and this fair land won from the wilderness by the daring and toil and endurance of our fathers, abandoned by us to the swarming hordes of Europe, Asia and Africa.

At the same time it is not wise for us to adopt a policy of non-intercourse with the rest of the world. The part is not greater than the whole. Our civilization is European civilization, the world civilization of today. When that falls, ours falls. What we need is intelligent study of the whole question of population, the factors that enter into its increase, its stabilization, and its ultimate control. The question should be approached in the academic spirit, without bias, without hysteria, without fanaticism, in a spirit of fairness to all races and conditions of men.

The teachings of biology agree with the teachings of religion as regards the whole duty of man. They show that everywhere and always the interests of the race are superior to the interests of the individual. They exalt altruism and condemn selfishness. Some of us thought, when we adopted different theories about man's origin, that we had come to the parting of the ways, and that thenceforth our paths would diverge, but we have been surprised again and again to find each other working shoulder to shoulder in the same great tasks of humanity and fighting as comrades for the right and against the wrong.

We have about concluded that our differences were over definitions merely, not realities.

"In the beginning God created the heavens and the earth," are the simple, grand words of the first chapter of Genesis. These are the words of a modern poet,<sup>2</sup> who has spent his life in the academic atmosphere of an American college:

A fire-mist and a planet,  
A crystal and a cell,  
A jelly-fish and a saurian,  
And caves where the cave-men dwell;  
Then a sense of law and beauty  
And a face turned from the clod,  
Some call it Evolution,  
And others call it God.

A picket frozen on duty,  
A mother starved for her brood,  
Socrates drinking the hemlock,  
And Jesus on the rood;  
And millions who, humble and nameless,  
The straight, hard pathway plod,  
Some call it Consecration,  
And others call it God.

<sup>2</sup> W. H. Carruth, *Each in his own tongue*. G. P. Putnam's Sons, N. Y. 1908.

# THE CYTOLOGY OF THE SEA-SIDE EARWIG, ANISOLABIS MARITIMA BON.

## PART I

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WITH THREE PLATES

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### 1. INTRODUCTION

The forficulid, *Anisolabis maritima* Bon., which is found under the stones and riff-raff at the high-tide mark, is especially beautiful material for cytological study. The chromosomes are clear and distinct; the cytoplasmic structure, nicely demonstrable; and good preservation is not difficult. The differentiation of the oöcyte and nurse cell and their subsequent growth present many interesting problems which will be taken up in another paper. The origin and distribution of mitochondria in both the sex and the embryonic cells may also be studied profitably in this species. For the present, the author has confined himself chiefly to the chromosome number, and the origin and fate of the sex-chromosomes in the male. The work was begun in the summer

of 1915, suffered many delays due to the World War, but was taken up again in the spring of 1920.

I wish to express my thanks to the American Association for the Advancement of Science, which, through its Committee on Grants for Research, has enabled me to purchase microscopical lenses suitable for cytological study. These lenses have aided greatly in the completion of the paper.

## 2. HISTORICAL REVIEW

Two of the Forficulidae have been previously worked upon from a cytological standpoint, *Forficula auricularia* and the present species, *Anisolabis maritima*; the bulk of the work having been done upon the former species. The accounts claim a great variability in the diploid and haploid number of chromosomes, and several combinations of sex-chromosomes have been described.

The most recent and detailed contribution to the cytology of the forficulids is that of Payne ('14) on the variability of the chromosomes of *Forficula*. Payne states that the spermatogonial metaphases show from 24 to 27 chromosomes, twenty-four being the most usual number. The spermatocytes were found to have from 11 to 14 chromatic elements present. Zweiger ('06) states that the spermatogonial count was 24 or 26, the latter number being the more prevalent. He states that either 12 or 13 chromosomes may appear in the primary spermatocytes, and 12 to 14 in the secondary spermatocyte metaphase plates.

Stevens ('10) considered 24 the correct spermatogonial number and 12 the haploid number, one of the twelve seen in the primary spermatocytes being an unequal hetero chromosome group, which separated reductionally in the first maturation division.

Pantel ('12), whose work deals mainly with the degeneration of cells due to the presence of protozoan or insect parasites, described a variable number of chromosomes in *Forficula*. Spermatogonia have either 25 or 26 chromosomes; and spermatocytes, 11 to 13 chromosomes. He does not insist, however, that

this variation, which had already occupied the attention of such pioneers as Carnoy, La Valette, St. George and Sinéty, should be produced by parasitism.

Brauns ('12), in his study of the oögenesis of *Forficula auricularia*, believes that the haploid number in the female is 13. He quotes Professor Ludwig Will of Rostock as saying that the male diploid number of *Forficula* is 25, and the female diploid number 26; but that some males show 24 chromosomes in their spermatogonia. It is a striking coincidence that my counts on *Anisolabis* are in very close agreement with the results of Professor Will.

Randolph ('08) worked on *Anisolabis* and described 24 chromosomes as the diploid number in both sexes. In the primary spermatocytes she pictures a pair of almost equal hetero chromosomes which lag in the anaphase of the first maturation mitosis, but her results are not at all in accord with those described in the present paper.

### 3. METHODS

The material studied consisted of gonads and embryos. Nymphs were found best for the study of the germ cells. The animals were all collected at or near Cold Spring Harbor, Long Island, during June, July and August of several summers since 1915.

The best fixatives were Flemming's fluid (strong), Bouin's fluid and Benda's modification of Flemming's fluid. Various stains were employed. The Flemming material was stained in Heidenhain's haematoxylin, counterstained with Orange G or with safranin and lichtgrün. The Benda material was stained either with alizarin and crystal violet, or with methyl green and acid fuchsin of Bensley. These last two were especially valuable in the study of the xxy-complex.

Smears of testes were made in a moist chamber, immediately exposed to osmic fumes for a few seconds, and then immersed in a fixing fluid; care being taken to avoid drying. Such smears were then treated and stained like sections.

Embryos were removed from their chorionic coverings before fixation in Flemming's fluid.

The abundance of material, the large number of preparations made, and the variety of methods employed lead the author to believe that his results are fairly accurate.

All drawings were made with the aid of a camera lucida, using a 1.5 mm. Zeiss apochromatic objective and a 20  $\times$  compensating ocular. This gave an initial magnification of 3300 diameters. The drawings were reduced in the reproductions, plate XXIV about one-third and plates XXV and XXVI about two-fifths.

#### 4. THE GONADS

Each testis consists of two long narrow tubules surrounded by a fat sheath. The length and narrowness of the tubules gives a good seriation of stages from the blind tip to the bottom where the sperm pass into the vas efferens. Near the blind or cephalic end of the tubule is a large apical cell, surrounded by young cysts of spermatogonia. These younger spermatogonial generations are larger cells and better for spermatogonial counts than those in cysts more caudad. The cysts are clearly marked off from one another by distinct walls. The spermatocytes undergo considerable growth in size and their cytoplasm acquires a large amount of mitochondria. The spermatocyte cysts occupy by far the greater part of the tubules in nymphal males. At no time during the growth period do the chromosomes disappear or lose their staining powers. The transition from ultimate spermatogonia to the formation of the spermatids must be rather slow, inasmuch as every stage in the conjugation of the chromosomes and the formation of the tetrads may be found in the testes of a single nymph, previous to the final moult. This is in marked contrast to many insects, in which the syndetic stages are very rare and difficult to find. One fortunate condition in the study of *Anisolabis* is the fact that each testicular tubule contains a large number of cysts and that each cyst shows slight variations in its meiotic phase.

Many testes show a central core of heterogeneous material made up of degenerating cysts. This looks much like the stream of food seen passing from the terminal chamber to the growing oöcytes of telotrophic insect ovarioles. It is not the purpose of the present paper to describe the details of the spermatogenesis or the cytology of degeneration, although the author hopes to attack these questions at another time.

The ovaries are composed of very long, and much attenuated tubules, each fastened at its narrow, cephalic end by a terminal filament reaching to the dorsal body wall. The sheath of each ovariole is composed largely of tracheal tubules, and undergoes rhythmic pulsations. The space between the egg string and this sheath is filled with a coagulable fluid. The cephalic tip of each ovariole, just caudad to the attachment of the terminal filament, is occupied by a Keimpolster; then follow oögonia, showing an occasional mitosis; while a trifle more caudad one may find pairs of oögonia both in the same mitotic phase. About one-tenth of a millimeter from the Keimpolster occur the ultimate oögonial mitoses. Here four cells all in the same stage of mitosis may be found, and each cell gives rise to an oöcyte and a nurse cell which continue in close connection and accompany each other from this time until the end of the growth period. Syndesis occurs immediately after the differential mitosis, the oöcyte here outstripping its sister nurse cell in size. Soon, however, the nurse grows much larger than the oöcyte, and, at about six-tenths of a millimeter from the Keimpolster, they orient in single file (oöcyte, caudad; nurse cell, cephalad), acquire follicular walls, and proceed in the accumulation of yolk material. The large nurse cell with irregular nucleus is surpassed finally in size by the oöcyte, and becomes a small cap on the cephalic end of the ovum.

## 5. THE DIPLOID CHROMOSOMES

### *A. The female*

Oögonia in their ultimate mitoses show 26 clear, distinct chromosomes, well separated from one another. Numerous drawings were made and the number 26 established without doubt. Fig-

ures 1-4 (Plate XXIV) represent four typical metaphase plates. Subsequent observations lead the author to believe that, of the twenty-six chromosomes, twenty-two are autosomes, and four are two double x-chromosomes, which appear in quiescent oögonial nuclei as two double and almost square karyosomes.

The female somatic number has likewise been established to be 26. The counts were made on well-developed embryos, treated by the same methods as the gonads. Numerous mitoses in the hypodermal cells and in the developing central nervous system offered abundant material for satisfactory counts. A suitable embryo would be selected and then sketches made of every distinct metaphase plate in the whole series of sections. Figures 5-8 (Plate XXIV) represent four groups showing 26 chromosomes each. These are selected from a single embryo in which dozens of clear counts of 26 were made. In the somatic cells, as has been noted by previous investigators, there is a much greater variation in the size of the cells and the form of the chromosomes (whether long and narrow, or short and broad) than there is in the germ cells. The chromosome number, however, remains constant, with the occasional exception of a giant cell with twice the diploid number present.

#### *B. The male*

Spermatogonia likewise have clear, clean-cut chromosomes, twenty-five in number, cells near the apex of the tubule serving best for such counts. These spermatogonia have a large amount of cytoplasm and the chromosomes are well separated (Plate XXIV, figs. 9-12). In the cytoplasm one may often encounter bodies, which might be mistaken for chromosomes in deeply stained haematoxylin preparations, especially after Bouin or sublimate fixation. In such preparations these cytoplasmic masses are quite as dark in color as the chromosomes and not greatly different in size from the average *Anisolabis* chromosome. These bodies are shown, light gray in tone, in figures 9, 11, and 12 of Plate XXIV. After Benda fixation these cytoplasmic bodies take mitochondrial stains, and stand out in marked contrast to the

chromosomes, being purple in crystal violet + alizarin, and red in methyl green + acid fuchsin. The use of these stains enables one to establish the number twenty-five for the spermatogonial chromosomes. As will be shown later, twenty-two of these are autosomes, two form an x-complex, and one is a y-chromosome.

The male somatic number was likewise established by the study of serial sections of embryos in which many counts of single individuals were made. Figures 13 to 16 (Plate XXIV) are typical 25 chromosome plates of such male embryos. The following important variation, the only characteristic one so far found in the study of *Anisolabis*, must be noted. In male embryos, with typical 25 chromosome cells, one finds clear metaphase plates with only 24 chromosomes. This happened too often to be purely accidental or due to error or oversight. A probable explanation of the phenomenon will be given in Part 8.

#### 6. THE SPERMATOCYTE CHROMOSOMES

The initial and most fundamental facts to be established were that twelve chromatic elements were uniformly present in primary spermatocyte metaphase plates (Plate XXV, figs. 28-29), and that half the secondary spermatocytes possessed twelve chromosomes and the other half had thirteen (Plate XXVI, figs. 44-47). These facts made necessary the careful study of the origin of the twelve primary spermatocyte chromosomes.

From the 25 spermatogonial chromosomes are formed eleven autosomal tetrads and a heterochromosomal hexad, which I have called the xxy-complex and which may be seen in figures 17-27 (Plate XXV). The autosomal threads and tetrad formation are omitted from these figures. The evidence is rather clear that the tetrads are formed by parasynopsis, and it is hoped that additional smear preparations will enable the author to deal with this point in more detail in another paper. Figures 17-22 show merely the nuclear outline and the xxy-complex, stained in iron-haematoxylin, the relative intensity of the stain being depicted as accurately as possible in the figures.

Figure 17 is an early leptotene stage, the autosomal threads just emerging from the telophase chromosomes of the ultimate

spermatogonial division. Here there is seen a double, rather angular body (xx), and a deeply staining sphere (y). With the establishment of the leptotene threads (Plate XXV, fig. 18), the xx-and the y-element come into close apposition and remain connected, sometimes merely by a small strand (Plate XXV, figs. 19, 20), and also during syndesis they continue this connection. When the zygotene threads are well formed, the xx-element separates from the y-element. Often they come to lie at some distance from each other in the nucleus, but apparently not under control of the centrosome at the positive pole of the nucleus (Plate XXV, figs. 21, 22).

With the beginning of the strepsinema the xx-element and the y-element again approach each other and are again connected by a narrow strand (Plate XXV, figs. 23, 24). The xx-element reveals its two-fold constitution, when viewed at a favorable angle in well-decolorized haematoxylin preparations, and especially well in crystal violet + alizarin slides. At the establishment of the strepsistene stage we notice the coalescence of the xx-and the y-element. In iron-haematoxylin the y-element has a lighter cortical zone, and a more deeply stained center. The doubleness of the x-portion is no longer so distinct (Plate XXV, figs. 25-26).

When the autosomal tetrads are formed, but are still very granular, there appears on the xxy-complex a highly refractive spherule (fig. 27, *nl*), which separates from its parent mass at about the time the smooth, deeply staining tetrads are established. This nucleolar body may then lie anywhere in the nucleus, even in close apposition to one of the autosomal tetrads. As the centrosome divides and preparation is made for the first maturation spindle, this nucleolar body diminishes in size and finally disappears, leaving eleven autosomal tetrads and the xxy-hexad to enter the metaphase plate.

Not only form but also differential reaction to stains enables one to trace the evolution of the hexad. In safranin + lichtgrün, the y-element is not so deep a red as the xx-component, in stages corresponding to those shown in figures 17-26. The y-element also appears vacuolated, and has a greenish tinge in the early

strepsinema. Finally in the later strepsistene stage, when the chromatic spherule is given off, the y-element stains as deeply as the two x-elements. In crystal violet + alizarin the y-element is purple, and the xx-element brown with small purple granules in it; whereas the nucleolar sphere of the late strepsinema is deep purple. In methyl green + acid fuchsin, the y-element is red, and the xx-element green. As the two fuse, in stages corresponding to figures 25 and 26, the y-element gradually loses its red color and becomes green, while the extruded nucleolar spherule is a deep red. We must, I believe, assume that the extrusion of this nucleolar spherule is in a vital way connected with the change in "stainability" of the y-element.

The twelve chromosomes of the primary spermatocyte metaphase (Plate XXV, figs. 28, 29) are so widely separated that, in lateral views with very high magnification, one may focus sharply on each element in the spindle. Good lateral views of the xxy-hexad may be obtained not only in metaphase plates (figs. 30-33) but also in anaphase stages (Plate XXVI, figs. 37, 38). Figure 34 (Plate XXV) shows the twelve elements of the metaphase plate viewed laterally, the chromosomes of the several foci being here transposed into a single row from the camera lucida drawing. The hexad is on the extreme right. Figure 35 represents a corresponding stage, but taken from a smear slide. The contents of the cell were so spread out that a single focus displayed all the chromosomes with no overlapping. In the smear slides the chromatic elements appear smaller but retain all the features seen in sections, and offer a very good check upon the latter.

The attachment of the y-element and the xx-element seems to be either terminal  $\begin{Bmatrix} y \\ x \\ x \end{Bmatrix}$  or lateral  $\begin{Bmatrix} y \\ xx \end{Bmatrix}$ . Various arrangements of the elements taken from metaphases and anaphases are seen in figures 30-38. Figure 36 (Plate XXV) shows seven separate xxy-hexads, the y-element in all cases being uppermost in the figures.

In the first meiotic division (Plate XXVI, figs. 37-41) the y-chromosome passes to one pole and the double x-chromosome

to the other. Figures 40 and 41 represent two anaphase plates of a single cell, similar to that shown in figure 39, but cut through the equatorial zone so that one section contains one plate and the next section its sister. In both plates eleven of the chromosomes, the autosomes, are similar; and the large xx-element in figure 41 and the smaller y-element in figure 40 occupy corresponding positions.

Following the telophase of the first meiotic division there is a definite interkinetic period with the establishment of a well-defined, nuclear membrane (Plate XXVI, fig. 42). The centrosome of the primary spermatocyte telophase remains visible and establishes the spindle of the secondary spermatocytes. The dyads remain rather distinct, deeply staining, block-like masses in the nucleus of the interkinetic stage.

With the formation of the secondary spermatocyte spindles we now have two distinct types of metaphase plates: those with twelve chromosomes, and those with thirteen (Plate XXVI, figs. 43-47). The twelve chromosome plates consist of 11 dyads and a y-chromosome. The thirteen chromosome plates consist of 11 dyads and two x-chromosomes, which separated from each other during the interkinetic period and are here represented by two discrete elements. Figures 46 and 47 (Plate XXVI) show two pairs of sister second spermatocytes, one in each pair containing twelve, and the other thirteen chromosomes. The former figure is taken from a section, the latter from a smear slide.

Occasionally giant secondary spermatocytes are formed with all the chromatic elements of the first maturation spindle present, the chromosomes having divided but the cytoplasm having failed to do so. Two such metaphase plates are shown in figures 48 and 49 (Plate XXVI) and each has 25, well-defined chromosomes.

The second maturation mitosis divides all the chromosomes equationally, and they pass to their respective poles without lagging. Figures 50 and 51 represent sister anaphase plates, drawn from a smear slide, and showing an exact correspondence in their chromatic elements. The spermatids (fig. 52) are formed

immediately after the telophase of the second meiotic division and bear a remarkable resemblance to the interkinetic spermatocytes, except that they are smaller and that their chromosomes soon break up into granules.

## 7. DISCUSSION

The author believes the female diploid number of chromosomes of *Anisolabis* to be twenty-six in both germ cells and somatic cells, as against twenty-four claimed by Randolph ('08) for both sexes. The normal male diploid number is twenty-five although somatic mitoses with twenty-four chromosomes are found.

The union of the two x-chromosomes into a single body is probably the explanation of this last phenomenon, and this supposition is strengthened by the fact that, in the growth of the spermatocytes and in the first spermatocyte division, these two x-elements of the xxy-hexad are in close apposition, leading to the assumption that the two parts are intimately related. The x-complex may be considered either as having originated from a single x-chromosome or as now being in the process of the formation of a single x-chromosome out of two previously distinct chromatic elements.

Another view of the 24 chromosome somatic male cells is possible: namely, that after a number of somatic divisions, the y-element undergoes a dissolution. From the behavior of the y-element in the growth of the spermatocytes, one may infer that it is greatly different from the normal chromosomes; for, not until the late strepsistene does it acquire a true chromatic stain, when tested with alizarin + crystal violet or with methyl green + acid fuchsin. Only after giving off the nucleolar spherule, which takes the mitochondrial stains deeply, does its definite chromatic nature appear.

Our interest in the y-chromosome must be again kindled in view of the recent type of inheritance described by Castle ('21) linked with this exclusively paternal chromatic element. We must try to determine whether the y-chromosome is a chromosome in a state of formation or whether it is merely a degenerate x-chromosome.

In regard to the sex-chromosome of the forficulids, the author would maintain that in *Anisolabis* we have neither unpaired accessory chromosomes, nor a pair of unequal heterochromosomes, nor a pair of almost equal heterochromosomes, as previously described by various authors. The following conditions are believed to exist: the female diploid number is 26, consisting of 22 autosomes and 4 x-chromosomes; the female haploid number (inferred) is 13, consisting of 11 autosomes and 2 x-chromosomes; the male diploid number is 25, consisting of 22 autosomes, 2 x-chromosomes, and a y-chromosome; half the second spermatocytes show 13 chromosomes, and the other half 12. The former gives rise to two female determining spermatozoa, containing 11 autosomes and 2 x-chromosomes; the latter gives rise to two male determining spermatozoa, with 11 autosomes and a y-chromosome.

It will be an interesting problem to see if the small mature males, occasionally found in *Anisolabis*, are in some way related to an upset in the normal chromosomal distribution described above.

#### 8. SUMMARY

1. The diploid number of chromosomes in *Anisolabis* is 26 in the female, and 25 in the male both in somatic and germinal cells.

2. The only variation from the above is in the male somatic cells, where only 24 chromatic elements may often be counted. This may be due to a fusion of the two x-chromosomes in the male cells or to the loss of the y-chromosome.

3. Primary spermatocytes show twelve chromosomes: eleven are autosomal tetrads, and one an xxy-hexad.

4. The xx-element together with 11 autosomal dyads pass into one secondary spermatocyte; the y-element and 11 autosomal dyads pass into the sister cell.

5. In the interkinetic period the two x-chromosomes separate and appear as discrete bodies in the second maturation spindle. We therefore find 13 chromosomes in one half the metaphase plates, and 12 chromosomes in the other half.

6. All chromosomes divide equationally in the second spermatocyte division, giving rise to female determining spermatozoa with 11 autosomes and two x-chromosomes, and male determining spermatozoa with 11 autosomes and a y-chromosome.

7. The y-chromosome of the spermatocyte is chemically and morphologically rather unlike the x-chromosomes during the growth period up until the late strepsinema, when it gives off a nucleolar spherule which takes mitochondrial stains.

*Granville, Ohio, June 28, 1921.*

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#### 10. EXPLANATION OF PLATES

All drawings were made with the aid of a camera lucida. A 1.5 mm. Zeiss apochromatic objective and a 20× compensating ocular was the optical combination used. All figures were drawn at 3300 diameters magnification and subsequently reduced, in Plate XXIV the reduction being about one-third and in Plates XXV and XXVI the reduction being about two-fifths.

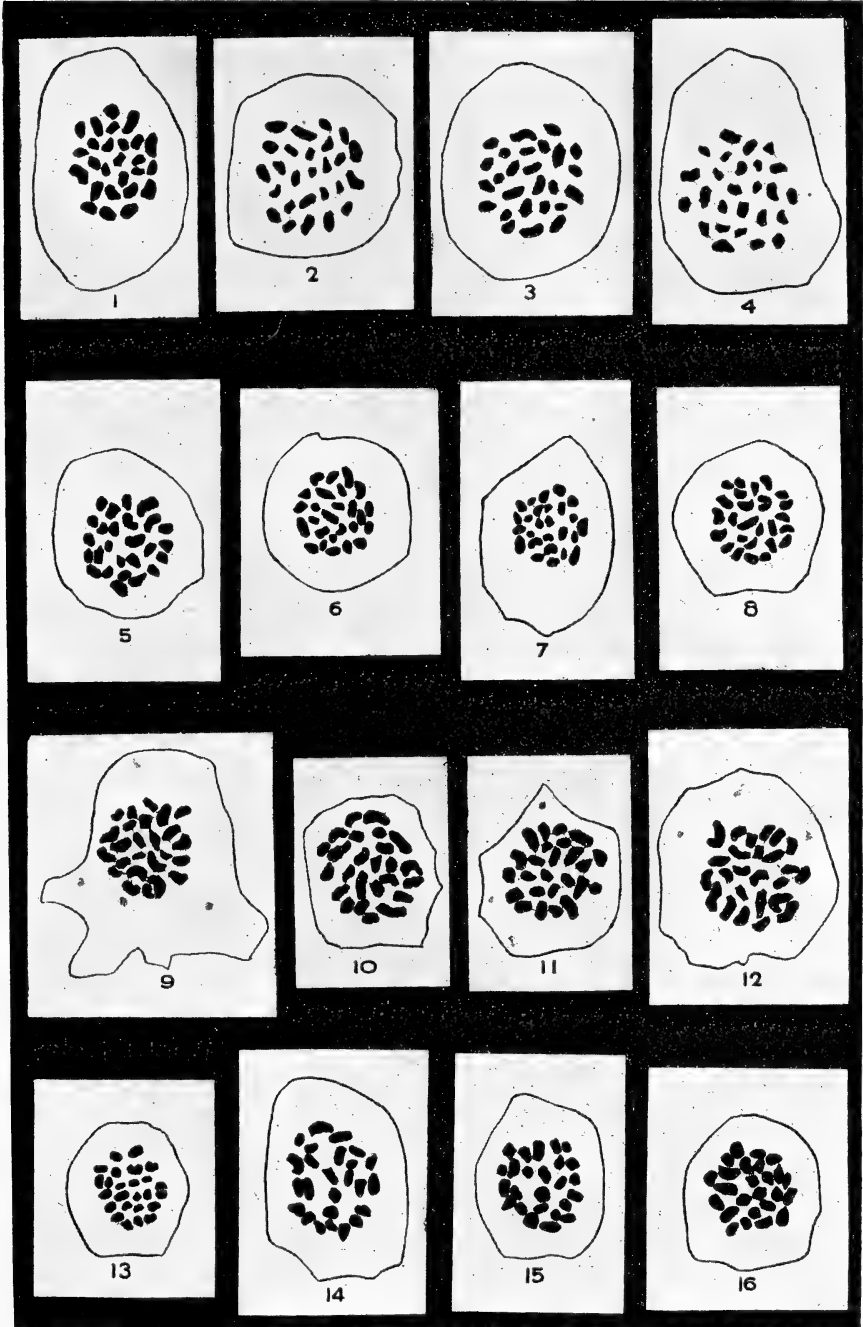
#### PLATE XXIV

Figs. 1-4. Oögonia, metaphase plates, polar view, 26 chromosomes.

Figs. 5-8. Somatic metaphase plates, polar view from female embryo, 26 chromosomes.

Figs. 9-12. Spermatogonia, metaphase plates, polar view, 25 chromosomes.

Figs. 13-16. Somatic metaphase plates, polar view from male embryo, showing 25 chromosomes.

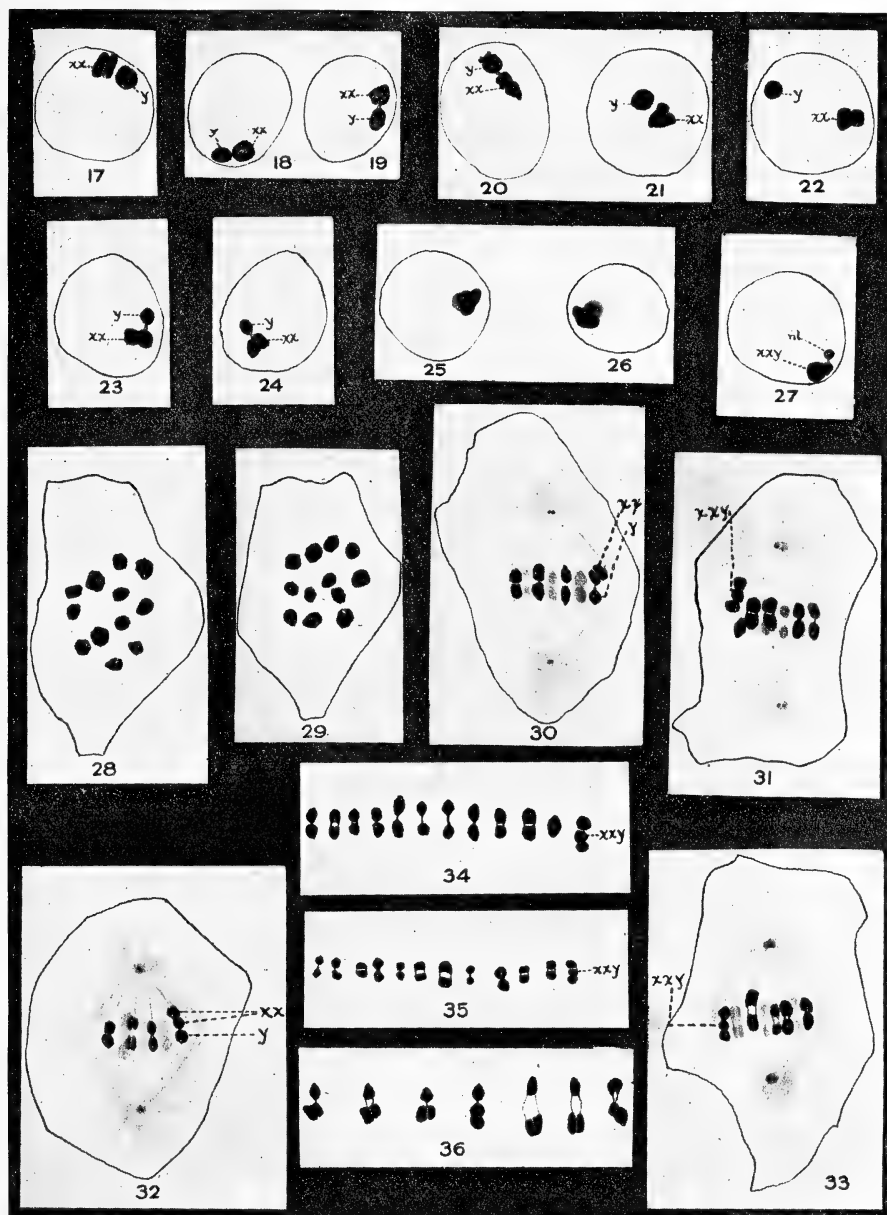


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## PLATE XXV

### PRIMARY SPERMATOCYTES

- Fig. 17. Early leptotene nucleus, showing xx and y  
Fig. 18. Trifle later stage than Fig. 17, xx and y in close apposition.  
Figs. 19-20. Nuclei of syndetic cells, xx and y connected.  
Figs. 21-22. Diplotene nuclei, showing separation of xx and y-elements.  
Figs. 23-24. Early strepsistene nuclei, showing reunion of xx and y.  
Figs. 25-26. Later strepsistene nuclei, showing fusion of xx and y.  
Fig. 27. Late strepsistene, showing the formation of the nucleolar spherule (nl)  
Figs. 28-29. Primary spermatocytes, metaphase plates, polar view, showing 12 chromosomes.  
Figs. 30-33. Primary spermatocytes metaphase, lateral view, showing xxy-hexad  
Fig. 34. The twelve chromosomes of a primary spermatocyte metaphase. xxy on extreme right, taken from a section.  
Fig. 35. Same stage as figure 34, except that it was taken from a smear slide.  
Fig. 36. Various forms of the xxy-hexad, as seen in metaphases and anaphases of primary spermatocytes viewed laterally. y-element shown above in each case.



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## PLATE XXVI

Figs. 37-38. Anaphases of primary spermatocytes, showing separation of xx and y. In figure 37, the hexad is in linear arrangement; in figure 38, the two x-chromosomes are placed side by side and the y-chromosoms is above.

Fig. 39. Late Anaphase of primary spermatocyte, the xx-element passing to the upper pole in the figure.

Figs. 40-41. Sister anaphase plates of cell corresponding to figure 39. In figure 40, the y-element is included; in figure 41, we see the xx-element.

Fig. 42. Interkinesis.

Fig. 43. Metaphase secondary spermatocyte, lateral view.

Fig. 44. Metaphase secondary spermatocyte, polar view, showing 13 chromosomes.

Fig. 45. Metaphase secondary spermatocyte, polar view showing 12 chromosomes.

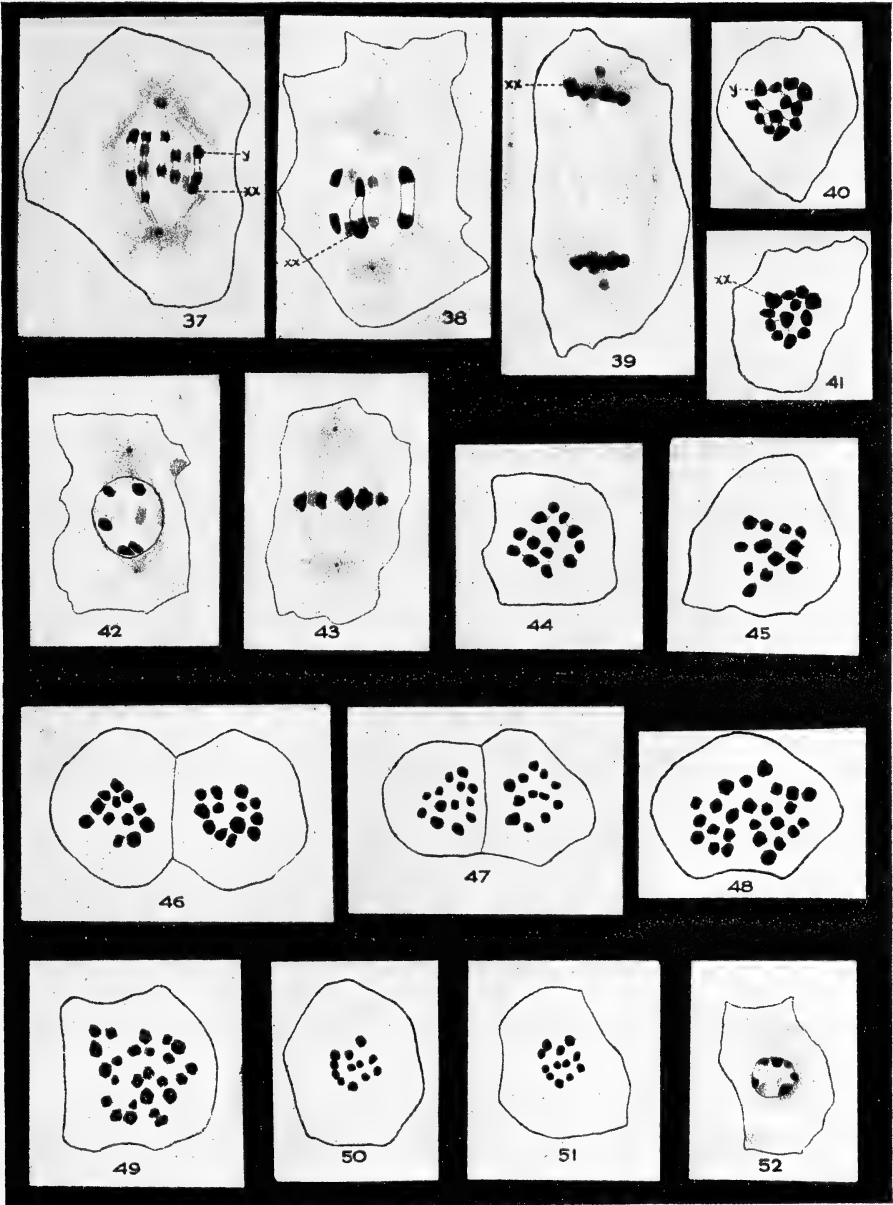
Fig. 46. Sister cells, secondary spermatocytes, metaphase, polar view: one showing 12, the other 13 chromosomes.

Fig. 47. Same stage as figure 46, but taken from a smear slide.

Figs. 48-49. Giant secondary spermatocytes, metaphase, polar view, showing 25 chromosomes

Figs. 50-51. Sister anaphase plates of a secondary spermatocyte (12 chromosome type), showing exact distribution of chromatin to spermatids.

Fig. 52. Spermatid, shortly after second meiotic division.



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## NOTES ON ARCTIC ORDOVICIAN AND SILURIAN CEPHALOPODS

CHIEFLY FROM BOOTHIA FELIX—KING WILLIAM LAND, BACHE  
PENINSULA, AND BEAR ISLAND

AUG. F. FOERSTE

To Dr. Olaf Holtedahl we owe a number of very valuable papers bearing directly on American Arctic geology. In 1912 he published his paper "On Some Ordovician Fossils from Boothia Felix and King William Land collected during the Norwegian Expedition of the Gjøa, Captain Amundsen, through the Northwest Passage" in the Videnskapsselskapets Skrifter, I, Mat-naturv. Klasse, 1912, No. 9. The fossil material of this expedition was collected by Lieutenant Godfred Hansen, the second in command. The fossils forming the subject of Dr. Holtedahl's paper were collected at two localities. One of these was at Cape Christian Frederick on the west coast of Boothia Felix, Longitude  $94^{\circ}$  west and Latitude  $69^{\circ} 30'$  north, where collecting was done in September 1903. The other was somewhere on King William Land. It is known that in 1903 Hansen collected fossils on the Pfeffer River on King William Land, about 20 miles west of Gjøa Harbor, where the expedition had wintered. This harbor is on the south coast of King William Land at Longitude  $96^{\circ}$  west. Unfortunately, on account of inadequate labelling, it is impossible now to determine from which of the two localities the various specimens under consideration were obtained. The fossils were identified by Dr. Holtedahl as *Receptaculites oweni* Hall, *Halysites* sp., *Columnaria* sp., with partly separated corallites, *Maclurites* sp., *Eurystomites* sp., *Actinoceras beloitense* (Whitfield), *Actinoceras* sp. (cf. *tenuiflum* Hall), and *Gonioceras occidentale* Hall (Holtedahl, Plate III. fig. 1). This is a Black River fauna. Judging from the promi-

nence of the oblique lateral ribs toward the ventro-lateral angles in the figure of the *Eurystomites* published by Dr. Hortedahl (Hortedahl, Plate II, fig. 1), this Nautiloid is a *Plectoceras* related to such Black River forms as *Plectoceras undatum* (Conrad) and *Plectoceras halli* (Foord). The siphuncle of the specimen identified as *Actinoceras beloitense* (Whitfield) (Hortedahl, Plate IV, fig. 2) appears to be too small for typical forms of that species. The form figured as *Actinoceras* sp. cf. *tenuifilum* (Hall) (Hortedahl, Plate III, fig. 2) was kindly loaned to the present writer by Dr. Hortedahl, and is figured on Plate XXVI of the present paper. It has shorter camerae and a smaller siphuncle than *Actinoceras tenuifilum*, and probably belongs to a new species of which more material is needed to discriminate it satisfactorily from other forms.

In the specimen figured by Hortedahl as *Endoceras* (*Cyclendoceras*) *annulatum* Hall (Hortedahl, Plate IV, fig. 1), the annulations are much stronger and the number of camerae in a length equal to the diameter of the conch is much less than in typical forms of that species. Moreover, it does not present the strong downward flexure of the annulations on the ventral side of the conch characteristic of typical *Cyclendoceras*. Its general appearance is more like that of a *Dawsonoceras*, but, in the absence of any knowledge of its siphuncle, it is impossible to state positively that it could not be a *Cyclendoceras*.

In addition Dr. Hortedahl loaned also a number of Actinoceroids, a part of which are here figured and described in the hope that further material may be collected elucidating these forms. One of these is named *Actinoceras amundseni* in honor of Captain Roald Amundsen, the leader of the expedition. The material forwarded includes also a peculiar orthocone, flattened on one side, for which the new term *Leurorthoceras hanseni* is proposed in honor of Lieutenant Godfred Hansen, the geologist of the expedition and the second in command. It is regarded as a new genus. The Actinoceroids and the species of *Leurorthoceras* just mentioned are regarded as of Black River age.

In 1913 the same Videnskabs-selskabet of Kristiania published Dr. Hortedahl's paper on "The Cambro-Ordovician Beds of

Bache Peninsula and the Neighboring Regions of Ellesmere Land" in No. 28 of the Report on the Second Norwegian Arctic Expedition in the "Fram" 1898-1902. This expedition was led by Captain Otto Sverdrup; Per Schei was the geologist of the expedition. Bache Peninsula lies between  $79^{\circ}$  and  $79^{\circ}16'$  north latitude on the eastern coast of Ellesmereland and extends as far eastward as  $74^{\circ}30'$  west longitude. Cape Camperdown forms its southeastern corner and Victoria Head its northeastern corner. The lowest strata on the peninsula are exposed at Cape Camperdown. From this locality Dr. Høltedahl figured a cranidium, a free cheek, and a pygidium under the term *Ptychoparia* sp. The strata at Cape Camperdown dip north-north-west and are overlaid stratigraphically by those at Victoria Head.

From the *Orthoceras* limestone, "a bed of light greyish-white limestone, about 350 ft. thick which cropped out midway up the vertical face of Cape Victoria Head," Dr. Høltedahl figured a cranidium of another *Ptychoparia* and a cranidium of *Iliaenurus*. In addition, sections of fossil fragments, especially of *Orthoceratidae*, are fairly common. Of these *Orthoceratidae* Dr. Høltedahl kindly loaned me a number of specimens. At first sight these appeared to be very unpromising material, consisting chiefly of fragments of conchs exposing oblique cross-sections of their interiors. In most cases not even enough of the conch is present even for generic determination. However, in several cases, by grinding away the matrix, enough of single conchs was revealed to admit of fairly detailed study. Two of these specimens are figured and described here under the terms *Clarkoceras høltedahli* and *Ellesmeroceras scheii*; the first is named in honor of Dr. Høltedahl, to whose paleontological studies we are indebted greatly in our knowledge of Arctic faunas, and the second is named in honor of Per Schei whose zeal in collecting made some of these paleontological studies possible and whose untimely death we mourn. The second species belongs to the *Endoceratidae*, but is regarded as differing sufficiently from typical *Endoceras* to warrant a distinct generic name. It has its nearest relatives among *Endoceratidae* of Canadian age.

*Clarkoceras holtedahli* is closely related to the genotype *Clarkoceras newtonwinchelli* (Clarke) from the Shakopee member of the Canadian in Minnesota. A third specimen, here figured but not described (Plate XXVII, figs. 4, A, B, C), possibly may be an Endoceratitic shell with a large siphuncle in contact with the ventral wall of the conch, as in *Cameroceras tenuiseptum* (Hall), but, in the absence of any definite knowledge of the siphuncle in this Bache Peninsula specimen, its generic reference remains impossible.

Dr. Holtedahl was inclined to regard the *Orthoceras* limestone specimens figured by him as Cambrian. There is a possibility of their being Ozarkian instead. *Illæenurus convexus* Whitfield occurs in the Mendota member of the Ozarkian in Wisconsin and several *Ptychopariae* occur in the Ozarkian of Point Levis, in Quebec, and in the Potsdam of New York and in the Kittatinny of New Jersey, of which the latter also are regarded as Ozarkian by Ulrich. Possibly both Ozarkian and Canadian horizons are represented in the *Orthoceras* limestone of Bache Peninsula, since the cephalopods here described have a distinctly Canadian appearance.

Above the *Orthoceras* limestone on Victoria Head is first a series of sandstones alternating with limestones, and next a "bed of close-grained brown limestone, about 100 feet thick, some of the layers of which are fossiliferous." From this brown limestone Dr. Holtedahl figures a *Hormotoma*, a *Maclurea*, and a *Bathyuriscus*. The genus *Hormotoma* is represented by numerous species in the Canadian. *Maclurea* also is represented by a number of species in the Canadian of Newfoundland, Vermont, and New York. If the pygidium figured from the brown limestone could be referred to *Bathyurus* or *Bathyurellus* instead of *Bathyuriscus* then again it would find numerous relatives in the Canadian. It seems possible, therefore, to regard the brown limestone in the upper part of the Victoria Head section as of Canadian or even of post-Canadian age.

From Victoria Head, in his work on "Palaeontology of the Coasts of the Arctic Lands" (Quarterly Journal of the Geol. Soc. of London, Vol. 34, 1878), Etheridge reports the discovery of *Maclurea magna* Leseur, a typical Chazy fossil.

From Norman Lockyer Island, about 8 miles directly north of Victoria Head, Dr. Hortedahl lists *Halysites gracilis* (Hall), *Calapoecia canadensis* Billings, *Streptelasma corniculum* Hall, *Mesotrypa* cf. *discoidea orientalis* Bassler, *Hallopora angularis* (Ulrich), *Rafinesquina deltoidea* (Conrad), *Plectambonites sericeus* (Sowerby), *Orthis tricenaria* Conrad, *Triplecia* sp., *Rhynchotrema inaequalvis* (Castelnau), *Trochonema umbilicatum* (Hall), *Gonioceras occidentale* Hall, *Thaleops ovatus* Conrad, *Nileus* (*Bumas-tus*?) sp., and *Leperditia fabulites* (Conrad). This is a characteristic Black River fauna, and is known to be wide spread in Arctic areas.

The paleontological results of the voyage of the "Fram" in the southwestern part of Ellesmereland were described by Dr. Hortedahl in his paper "On the Fossil Faunas from Per Schei's Series B in Southwestern Ellesmereland," which forms No. 32 of the series of Reports on the Second Norwegian Arctic Expedition in the "Fram" in 1898-1902, published by the Videnskabs-Selskabet of Kristiania, in 1914. By far the greater part of this report is concerned with the Helderbergian fauna of Southwestern Ellesmereland, equivalent to the Keyser of Maryland; however, lower faunas also are mentioned. Three Niagaran species, *Strophonella* cf. *euglypha* (Hisinger), *Conchidium arcticum* Hortedahl, and *Ceraurus* sp., are described from Baadkap, 30 miles southwest of the southwestern corner of Ellesmereland, on the northern shore of North Devon. Three species, probably of Black River age, are listed from South Cape, on the west side of the mouth of Harbour (Havne) Fjord, on the south shore of Ellesmereland, at 84° 30' west longitude; these species are *Halysites* cf. *gracilis* (Hall), *Strophomena* sp., and *Maclurites* sp. This Black River horizon is underlaid by 1300 to 1600 feet of strata consisting of limestone conglomerates with marly shales and pure limestones which possibly correspond to the Canadian and Ozarkian strata of the Bache Peninsula.

Dr. Hortedahl's "Notes on the Ordovician Fossils from Bear Island collected during the Swedish Expeditions of 1898 and 1899," published in 1918, form No. 1 of volume V of the Norsk Geologisk Tidsskrift. Bear Island is a small isolated island

about two thirds of the distance from Norway to Spitzbergen. Here A. G. Nathorst collected in 1898 the bulk of the fossils studied by Høltedahl. This was supplemented by material collected in 1899 by J. G. Anderson, which, however, did not contain much that was new. Both collections are deposited in the Riksmuseet, at Stockholm, Sweden. These collections consist of Black River fossils occurring in the upper part of the Hecla hook system in a series of strata known locally as the Tetradium limestone. From this Tetradium limestone the following species were listed: *Tetradium* cf. *syringoporoides* Ulrich, Bryozoa several species, Crinoid stems, *Rafinesquina* sp., *Orthoceras* (*Kionoceras*) sp. (Høltedahl, Plates XI, fig. 2), *Endoceras* (*Vaginoceras*) sp. (Høltedahl, Plates X, fig. 1), *Endoceras* (*Cyclendoceras*) sp. (Høltedahl, Plate IX, fig. 5), and *Gonioceras* (*occidentale* Hall?) sp. (Høltedahl Plate XI, fig. 3); also various Actinoceroids (Høltedahl, Plate X, figs. 2, 3, and Plate XI, fig. 1).

Regarding these species Dr. Høltedahl emphasizes the fact that *Tetradium* and *Gonioceras* are typical American genera, well represented in North America, while in Europe *Tetradium* is listed only from the Borkholm in the Baltic area and *Gonioceras* apparently does not occur at all. In Asia, moreover, *Gonioceras* is known only at a single locality, in West Shantung in North China, where it occurs associated with *Actinoceras* aff. *tenuifilum* Hall, another typical American Black River species. Regarding *Actinoceras*, Dr. Høltedahl states that this genus may be said to be characteristic of the American faunal province in Ordovician times, while in Silurian times it has spread also to Europe and is found quite commonly in England and in the Scandinavian-Baltic regions. A true *Actinoceras*, somewhat resembling the Silurian *Actinoceras imbricatum* Hisinger, is quite common in the uppermost Ordovician of some districts at the western side of the Kristiania region, in Hadeland and Ringerike. This Norwegian occurrence possibly may indicate that the *Actinoceras* stock came from the west or northwest in upper Ordovician times and spread in Silurian times all over southern Norway and Sweden.

During the summer of 1898 Dr. Høltedahl spent five weeks on Bear Island. The results of his investigations were embodied in his paper "On the Paleozoic Series of Bear Island, Especially on the Hecla Hook System," forming part II of volume V of the *Norsk Geologisk Tidsskrift*. In this paper he adds *Maclurites* sp. and *Gonioceras nathorsti* Høltedahl (Høltedahl, Plate XIV, fig.) to his former list of fossils from the *Tetradium* limestone of Bear Island, figuring both species. In addition he figures a vertical section of an Actinoceroid identified as *Actinoceras bigsbyi* Brönn (= *A. tenuifilum* Hall?) (Høltedahl, Plate XIII, fig. 5); the latter is refigured in the present paper and the term *Actinoceras tenuifilum ursinum* is proposed for it in allusion to its occurrence on Bear Island. Moreover, for the species figured in the preceding paper as *Orthoceras* (*Kionoceras*?) sp. (Høltedahl Plate XI, fig. 2), the name *Kionoceras høltedahli* also is proposed here.

However, the chief new feature of the second paper by Dr. Høltedahl on the Geology of Bear Island is the proof which it brings of the presence of Canadian strata on that island. These species occur in the younger dolomite series of the Hecla Hook System, beneath the *Tetradium* limestone horizons. The following forms are listed: *Calathium* cf. *pannosum* Billings, *Calathium* sp., *Archaeoscyphia* (*minganensis* Billings?) sp., Crinoid stems, *Maclurites* sp., *Liospira* sp., *Lophospira* sp., *Orthoceras* sp., Cyrtoceraconic shell, and *Piloceras* cf. *explanator* Whitfield (Høltedahl, Plate XII, fig. 6; see also Plate XIII, fig. 3). The significant genera of this list are *Calathium*, *Archaeoscyphia*, and *Piloceras*, which Dr. Høltedahl recognized not only as characteristic of the Canadian but as having their main distribution in Newfoundland and in Eastern Canada.

In the present paper the species listed by Dr. Høltedahl as *Orthoceras* sp. Høltedahl (Plate XIII, fig. 1), is refigured as *Protocycloceras* cf. *lamarcki* (Billings), and the *Cyrtoceraconic shell of uncertain genus* (Høltedahl Plate XIII, fig. 2) is refigured under *Deltoceras* (?) sp., to indicate its Nautiloid character and not because its genus is definitely known.

On Bear Island the younger dolomite series of the Heclahook system is underlaid by the slate-quartz series, and the latter by the older dolomite series. These older dolomite rocks contain oolitoids and stromatolites, both chemical precipitates of carbonate of lime induced by the chemical activities of primitive plants; some of the stromatolites are of the *Cryptozoon* type, others are of the *Gymnosolen* type. The lower dolomitic rocks are correlated with the Ozarkian of North America.

From these studies by Dr. Høltedahl it is evident that three American series of Ordovician rocks had a wide distribution in Arctic areas; these are the Ozarkian, Canadian, and Black River. All three are recognized on Bear Island, and all three appear to have their lithological equivalents on Spitzbergen. Moreover, the two lower series appear to be represented also in Finmarken at the extreme northern end of Norway. Here the Ozarkian or older dolomite series of Bear Island is represented by the Porsanger series, and the Canadian or younger dolomite series of Bear Island finds its equivalent in the Varanger and Raipas series.

The Canadian age of the strata exposed at Durness, in the extreme northwestern corner of Scotland, has been known for a long time owing to the occurrence there of the very diagnostic species *Piloceras invaginatium* Salter. *Orthoceras mendax* Salter is an annulated form with a relatively large subcentral siphuncle which may turn out to be a *Protocycloceras*, a typical Canadian genus. Three species with very oblique annulations occur; these are *Orthoceras baculoides* Blake, *Orthoceras durinum* Blake and a form identified as *Orthoceras arcuoliratum* (?) Hall. In *Orthoceras durinum* the siphuncle probably is marginal. The general aspect of these species is Canadian. If their siphuncles were better known they probably would prove related to the *Endoceratidae* rather than to the *Orthoceratidae*. *Orthoceras pertinens* Blake, however, appears to be a typical *Orthoceras*. Among other forms identified from the Durness limestone are *Ophileta compacta* Salter and *Maclurites matutinus* (?) Hall, both of which are typical Canadian forms.

The species listed by Wyatt-Edgell as *Endoceras eoum* and described by Blake as *Orthoceras* (*Conoceras*) *eoum*, from the Arenig of Shelve, in the western part of Salop county, in Wales, also has a Canadian aspect. The siphuncle is marginal and equals two-sevenths of the diameter of the conch. On reaching the siphuncle the septa "bend slightly upward toward the aperture; though the chambers here stop short, the septa are continued over the siphuncle slightly bending upward, and along the latter is a depressed line." On the relationship of this species Blake adds: "This can not be an *Endoceras*, as the septa certainly do not make sheaths pointing backwards." Apparently this shell bears some resemblance to *Ellesmeroceras scheii* described in the present paper from Bache Peninsula.

Such species as *Actinoceras cochleatum* (Schlottheim), *Endoceras festinans* Blake, and the form identified as *Endoceras brongniartii* Troost suggest the Black River age of the Bala beds of Great Britain. The Llandeilo fauna of the Girvan district also contains American elements, such as *Maclurites logani*, a typical American Black River form.

On continental Europe, however, in the Scandinavian-Baltic areas, Ordovician faunas quite distinct from the American types prevail, as though some barrier had intervened, forming an eastern limit to the American Ordovician seas.

These conclusions are expressed by Dr. Høltedahl in the following terms:

In the Bear Island a fauna occurs of which we can say that it is no more closely connected with the Scandinavian-Esthonian than are the American equivalent faunas themselves. In the writer's opinion this fact gets its most probable explanation by assuming a land barrier between two different districts of sedimentation of middle Ordovician time, the one characterized by an American-Arctic, the other by a Scandinavian-Baltic faunal element. The many facts pointing towards the existence—at a corresponding time—of a land mass to the north-west of the northernmost, stratigraphically more fully known districts of Southern Norway and Sweden, the Mjösen district in Norway and Jemtland of Sweden, support this supposition. In Scotland a land is generally assumed to have been present in middle Ordovician time in

the far northwest, while further to the southeast the marine Llandeilian strata were deposited. Here we find the interesting Girvan deposits in which certain American faunal elements can be traced.

Regarding the place of origin and the early centers of distribution of gasteropods and cephalopods Dr. Ulrich has submitted the following observations:

The oldest, in everywise unquestionable, fossil record of the coiled gasteropods and cephalopods is found in Ozarkian rocks. In fact these classes constitute the most important parts of the middle and later faunas of this period as developed in the Mississippi Valley. As but few species of these classes are found elsewhere in rocks of this age, it is assumed that the gasteropods and cephalopods originated in oceanic basins to the south of the Mississippi embayment, that is in the Gulf of Mexico, Caribbean Sea or South Atlantic. From there they spread to the north and west, attaining before the close of the Canadian period rather general distribution in the continental seas of North America. However, judging from the Baltic section, they seem not to have reached the European side of the Arctic until well into the Ordovician (post-Canadian). About the same time, or perhaps in the somewhat later Black River epoch, certain types of cephalopods, like *Gonioceras*, spread from the Arctic into the Pacific. (Revision of the Paleozoic Systems, Bull. Geol. Soc. America, 22, 1911, p. 503.)

Regarding the crinoids, Dr. Ulrich states:

The crinoids seem to have originated during the early Ordovician (post-Canadian) in the southern middle Atlantic, where the dominant types, as expressed in the invading Gulf faunas of this age are Dendrocrinidae, Hybocrinidae, and Rhodocrinidae. During the Silurian the Gotland crinoids, like the corals, spread freely through the Arctic and then southward in America to northern Illinois. They extended also southward into England, where a slightly different development obtained, and thence into the Atlantic to the Gulf of Mexico and the Mississippi embayment. All the succeeding Paleozoic crinoid faunas, so far as known, originated in and spread from the Atlantic basins. (Ibid., p. 502.)

Regarding the time of origin of the crinoids it is interesting to note that, according to Dr. Hortedahl, fragments of silicified

crinoid stems are common in the Canadian strata of Bear Island. Moreover, fragments of crinoid stems are common also in some of the rock specimens belonging to the Black River strata of Bear Island.

In view of the wide distribution of Black River strata in Arctic areas it is interesting to observe that only three species of crinoids have been described so far from American Black River strata, and all of these were found in the northern part of the Mississippi embayment. These 3 species are *Carabocrinus dicyclicus* (Sardeson) from the Decorah of St. Paul, Minnesota, and of Ellsworth, Wisconsin; *Cremacrinus punctatus* Ulrich from the Decorah of Minneapolis, Minnesota; and *Porocrinus pentagonius* Meek and Worthen from the Platteville of Dixon, Illinois. In the matrix of the Black River strata in the Boothia Felix-King William Land area and from the Cape Chidley area in northern Labrador, only very depauperate stems of crinoids or cystids occur. Unfortunately it is not known on what basis the Bear island Canadian and Black River stems were interpreted as crinoidal rather than as cystidean. That cystidea are of much earlier origin than crinoidea has long been known.

Among the Silurian faunas invading North America by way of the Mississippi embayment are the Brassfield, typical St. Clair, Osgood, Rochester, Waldron, and Brownsport, while the Waukesha, Racine, Lockport, and Guelph represent invasions from the north. (Ulrich, *ibid.*, pp. 558-561). Regarding the migration of Gotlandian faunas from Scandinavian-Baltic areas across the Arctic into the Racine seas of Wisconsin and adjacent Illinois, it is unfortunate that our knowledge of Niagaran faunas in Arctic areas still is so inadequate. In my opinion, no equivalent of a Gotlandian fauna has been recorded so far in American Arctic regions.

From Offley Island, at the mouth of Petermann's Fjord on the west coast of Greenland, at 81°16' north latitude, came the forms described and figured by Foord as *Orthoceras arcticum* Foord and *Orthoceras darwini* Billings. The first of these is a cyrtoceraconic shell closely allied to an undescribed form in the Racine of the Wisconsin area, while the second is the familiar

*Kionoceras myrice* Hall and Whitfield from the Cedarville of Ohio which is the Ohio equivalent of the Racine of Wisconsin. *Actinoceras backi* Stokes was identified by Foord from Bessels Bay, about 20 miles southwest of Offley Island, and from Cape Louis Napoleon, 120 miles southwest of Bessells Bay and 35 miles northeast of Bache Peninsula. Another *Actinoceroid* was found at Dobbin Bay, directly west of Cape Louis Napoleon.

*Trochoceras boreale* Foord was described from Wellington Channel, between North Devon and Cornwallis Islands. It appears related to the Ordovician *Eurystomites* among the *Tarphyceratidae*. *Orthoceras griffithi* Haughton, a vertically striated species, was described from Griffith's Island, south of the middle of Cornwallis Island. *Endoceras ommaneyi* Salter was described from Assistance Bay, on the southern coast of Cornwallis Island. According to Haughton it was a cyrtoceraconic shell.

Actinoceroids appear to be relatively common on Southampton Island, which blocks the northern end of Hudson Bay, and Actinoceroids are common also in the Silurian areas west of Hudson and James Bays.

To me the affinities of these American Arctic cephalopods are with American forms, especially of Racine and Drummond Island type, and not with those of the Scandinavian-Baltic areas. However, such a minute part of the great Arctic regions has been investigated so far that it easily is possible for Silurian zones of European facies to turn up elsewhere in Arctic areas some time in the future. The vastness of these Arctic areas may be realized from the fact that Greenland is as long as the distance from Ottawa in Canada to Cuba; Baffin Land is as long as the distance from Cincinnati, Ohio to Portland, Maine. Ellesmereland is as long as the distance from Cincinnati to the Gulf of Mexico. At least half a dozen of the lesser islands equal in size at least two-thirds of that of the state of Ohio. Evidently there are innumerable possibilities of future discoveries.

The present paper was inspired by Dr. Høltedahl's extremely important communications on the geology of various Arctic areas, briefly reviewed on the preceding pages. While engaged on the study of Arctic Ordovician and Silurian cephalopods the

writer has felt continually the necessity of bringing together from various sources all available material for purposes of direct comparison. In view of the extreme rarity of Arctic cephalopod material, especially from some of the horizons and localities studied by Dr. Hortedahl, the writer requested the loan of such cephalopods as were at hand, and to the kindness of Dr. Hortedahl I owe the privilege of reexamining the material already once worked over by him. While the following pages do not add materially to the observations made by Dr. Hortedahl it is hoped they may be of some service owing to more detailed description and additional illustrations of the cephalopods.

As will be noticed in the following descriptions, most of the Arctic specimens here considered present sufficient detail to be of interest, and yet fall short of furnishing enough evidence for definite specific or, in a few cases, for generic reference. The lack of definite knowledge of the relation of the siphuncle to the cross-section of the conch in the *Actinoceroids*, and of the structure of the siphuncle in the supposed *Cyclendoceroids*, is especially unfortunate. What here is attempted is to secure all available evidence from such material as actually is at hand, in the hope that sooner or later it may lead to the securing of additional material. Such differences of opinion as here are expressed are made possible by lack of sufficient evidence, and evidently would disappear if more complete material could be secured.

#### LIST OF SPECIES

##### Gasteropoda, Canadian

1. Cf. *Euconia quebecensis* Billings.

##### Cephalopoda, Canadian

2. *Clarkoceras hortedahli* Sp. nov.
3. *Eremoceras syphax* (Billings); type.
4. *Ellesmeroceras scheii* Gen. et Sp. nov.
5. *Protocycloceras lamarcki* (Billings); types
6. *Protocycloceras whitfieldi* Ruedemann.
7. *Protocycloceras* cf. *lamarcki* (Billings); Bear island form.
8. *Deltoceras* (?) sp.
9. *Kionoceras laqueatum* (Hall); type.

##### Black River and Trenton

10. *Kionoceras hortedahli* Sp. nov.
11. *Kionoceras trentonense* Sp. nov.

12. *Kionoceras* sp.; from Trenton of Middleville, New York.
  13. *Kionoceras kentlandense* Kindle and Breger.
  14. *Leurorthoceras hansenii* Gen. et Sp. nov.
  15. *Leurorthoceras chidleyense* Sp. nov.
  16. *Actinoceras tenuifilum* (Hall); types.
  17. *Actinoceras* sp.; Boothia Felix-King William Land area.
  18. *Actinoceras amundseni* Sp. nov.
  19. *Actinoceras* sp.; Høltedahl's figured specimen.
  20. *Actinoceras* sp.; Boothia Felix-King William Land area.
  21. *Actinoceras tenuifilum centrale* Var. nov.; New York.
  22. *Actinoceras* cf. *tenuifilum centrale*; Boothia Felix-King William Land area.
  23. *Actinoceras tenuifilum ursinum* Var. nov.
  24. *Actinoceras parksi* Sp. nov.
  25. *Cyclendoceras annulatum* (Hall).
  26. *Cyclendoceras* or *Dawsonoceras*.
- Ordovician age uncertain.
27. *Eurystomites* (?) boreale Foord.
- Helderbergian
28. *Orthoceras* sp.

# 1. Cf. *Euconia* (?) *quebecensis* (Billings)

## *Plate XXVII, fig. 1*

*Pleurotomaria quebecensis* Billings, Pal. Foss. 1, Geol. Surv. Canada, 1865, p. 190, fig. 174:

*Pleurotomaria* (*Euconia*?) *quebecensis* Bassler, Bibliographic Index of Am. Ordovician and Silurian Fossils, 1915; gen. ref.

Height of shell 17 mm.; apical angle 62 degrees. Volutions about 9, surrounding a deep conical umbilicus having an apical angle of about 30 degrees. Vertical sections of the volutions tend to have a trapezoidal outline. In these sections the outer surface of each volution is moderately convex. The inner surface, of each volution along the umbilicus, is very slightly convex along its upper half, but along its lower half it is very strongly convex curving strongly outward at its base. The line of contact between successive volutions curves slightly downward along most of its length but at its outer extremity there is a slight tendency toward reversal of curvature. The shell is very thin, but distinctly outlined in the matrix. The specimen consists chiefly of a vertical section through the center of the

spire, but at its base it exposes a short part of the length of the two lower volutions.

Locality and Horizon.—From the *Orthoceras* limestone at Victoria Head on Bache peninsula, in Ellesmereland, west of Smith Sound. The horizon is regarded as of Canadian age. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Per Schei in May, 1899, on the Second Polar Voyage of the "Fram" under Captain Sverdrup.

Remarks.—Since typical *Euconia* is of Canadian and Chazyan age it would be interesting to discover this genus in the *Orthoceras* limestone of Victoria Head. In its apical angle and in the large size of its open umbilicus the species here figured and described resembles the vertical section of *Pleurotomaria* (*Euconia*?) *quebecensis* figured by Billings, but here the resemblance ends. The Victoria Head specimen has an extremely thin shell, there is no trace of lines of growth or of a slit-band, and the inner outline of the volutions is much more angular.

## 2. *Clarkoceras holtedahli* Sp. nov.

*Plate XXVII, figs. 2A, B; Plate XXXIII, fig. 1*

Specimen consisting chiefly of the upper part of the phragmacone; to this is attached that part of the basal portion of the living chamber which is adjacent to the siphuncle. The phragmacone is estimated to have had a height of at least 60 mm. The dorso-ventral diameter at the base of the living chamber is estimated at 47 mm., and the dorso-ventral apical angle was between 35 and 40 degrees. The conch is strongly compressed laterally, the lateral diameter at the base of the living chamber being estimated at 25 mm. The conch is slightly curved lengthwise in a dorso-ventral direction. The location of the siphuncle is endogastric, or on the concavely curved side of the conch. Here the curvature equals about 1 mm. in a length of 25 mm. The opposite side of the conch is curved in a convex direction, apparently at about the same rate as the concavely curved side.

Five camerae occupy a length of 16 mm., measured along the lateral side of the specimen; 2 additional camerae of about the

same height are exposed in the vertical section exposing the siphuncle; this is followed by a shorter camera, and a trace of a second shorter camera. From this it is concluded that the conch was mature. The sutures of the septa are directly transverse to the axial diameter of the conch. At the base of the specimen the dorso-ventral curvature of the septum has a radius of 25 mm., and its radius of lateral curvature is scarcely 12 mm. The siphuncle is almost in contact with the adjacent wall of the conch. At the base of the living chamber the dorso-ventral diameter of the siphuncle is about 7 mm., or about one-seventh of the dorso-ventral diameter of the conch. At the base of the specimen the dorso-ventral diameter of the siphuncle is slightly over 4 mm. The segments of the siphuncle intercepted between successive septa present slightly concave vertical sections along their walls. The lower margin of one segment invaginates into the upper part of the segment next beneath. The thickness of the siphonal wall is greater than that of the septa. There is no trace of an endocone.

Locality and Horizon.—From the *Orthoceras* limestone on Victoria Head, at the northeastern angle of Bache Peninsula; regarded as of Canadian age. Collected by Per Shei in May, 1899. Deposited in the Palaeontologisk Museum, Kristiania, Norway.

Remarks.—This species almost certainly is congeneric with *Clarkoceras newton-winchelli* (Clarke), although it has not been possible to prove that the segments of the siphuncle are annular connecting rings, and not prolongations of the septal funnels as in the *Endoceratidae*. In *Cyrtocerina* the interior of the siphuncle has transverse ridges alternating with the septa between the camerae. I do not know the structure of *Cyrtocerina* well enough to determine whether this appearance of internal transverse ridges indicates a structure generically different from that of *Clarkoceras*. In such specimens of *Cyrtocerina* as I have seen only the casts of the interiors of the camerae have been retained, the substance of the siphuncle having disappeared.

*Clarkoceras newton-winchelli* is from the Shakopee division of the Canadian in Union township in Houston county, Minnesota.

The type of *Cyrtocerina*, namely *Cyrtocerina typica*, is from the Leray division of the Black River at Pauquette Rapids, on the Ottawa River, in Canada. A second species, *Cyrtocerina mercurius*, was described by Billings from the Levis division of the Canadian at Point Levis, in Quebec, Canada. A third species, now known as *Cyrtocerina madisonensis*, was described by Miller from the Saluda member of the Richmond at Madison, Indiana, and a fourth species, *Cyrtocerina* (?) *schoolcrafti*, was described by Clarke from the Decorah division of the Black River near Cannon Falls, Minnesota. It is not certain that all of these are congeneric.

Among all these species, the relationship of the Victoria Head species described above, under the name *Clarkoceras holtedahli*, appears nearest to the Canadian genotype, *Clarkoceras newton-winchelli*, thus favoring the Canadian age of the enclosing strata at Victoria Head.

### 3. *Eremoceras syphax* (Billings)

*Plate XXXIII, figs. 8 A, B, C; fig. 2*

*Cyrtoceras syphax* Billings, Pal. Foss., 1, Geol. Surv. Canada, 1865, p. 194, text fig. 178.

*Eremoceras syphax* Hyatt, Proc. Boston Soc. Nat. Hist., 22, 1884, p. 282, Genotype.

Type specimen.—Conch slightly curved lengthwise along its dorsal side, the radius of convex curvature of the latter being about 100 mm. The ventral side is either straight or too faintly concave to be measured for curvature, at least in the type specimen. This specimen consists of the living chamber with 11 camerae and part of a twelfth camera still attached. The height of the living chamber is 18 mm. along its dorsal side; the margin of the aperture slopes gently downward from the dorsal toward the ventral side, so that the height of the living chamber along its ventral side is estimated at about 15 mm. The upper part of the shell of the living chamber is thickened slightly interiorly for a distance of 8 mm. from the aperture. On the cast of the interior of this chamber this thickening of the shell is indicated by a slight constriction of the upper part of the cast.

The conch is compressed laterally, the lateral diameter at the aperture being 19 mm., the dorso-ventral one being estimated at 23 mm. The corresponding diameters at the base of the living chamber are 16 and 19 mm. respectively. The lower 9 camerae occupy a length of 14 mm.; the upper 3 camerae, however, occupy a length of only 3.8 mm., each being successively shorter and the uppermost being only 1 mm. in length, thus indicating that the specimen was mature.

Along the dorsal side of the conch the sutures of the septa are almost directly transverse. On the lateral sides they curve at first gently downward, and then, on approaching the siphuncle, the sutures rise strongly upward. The septa, as far as known, are only moderately concave. The siphuncle has a lateral apical angle of 15 degrees. At the base of the living chamber its lateral diameter is 7 mm. At the base of the specimen its lateral diameter is 2 mm. The original length of the phragmacone of a complete specimen may have been 20 mm. The ventral side of the siphuncle apparently was in contact with the ventral wall of the conch along almost its entire width, thus agreeing with the latter in its lateral curvature. Along the side facing the interior of the conch, the siphuncle was more convex laterally, so that the cross-section of the siphuncle must have resembled somewhat that of a *Tripteroceas*, in the flattening of one side and the greater convexity of the opposite side. Between successive septa the walls of the siphuncle curve slightly inward, suggesting an Endoceratitic structure, successive funnels extending downward the length of one camera and invaginating into the neck of the funnel next beneath.

The cast of the interior of the conch is marked by faint vertical ribs, both on the phragmacone and on the living chamber, there being possibly 35 or 40 ribs within the circumference of the living chamber. Along the living chamber there are also several very faint annulations, with crests about 3 mm. apart. These annulations slope downward from the dorsal toward the ventral side of the conch at an angle agreeing with that of the margin of the aperture, but at a rate greater than that of the sutures of the septa. Whether these very obscure vertical ribs and transverse

annulations indicate corresponding markings on the exterior of the shell is unknown.

Locality and Horizon.—Found at Point Levis, Quebec, in the Levis representative of the Canadian formation. Type, numbered 819, in the collections of the Geological Survey of Canada.

Remarks.—The preceding description of the type of *Eremoceras syphax* differs necessarily from those previously presented, since only the dorsal side was exposed when the specimen was studied by Billings and Hyatt. Recently, however, the writer removed all of the surrounding matrix, thus exposing for the first time the large siphuncle. What formerly had been regarded as the siphuncle apparently was a slight discoloration along the median line of the dorsal side, and this had been emphasized by vertical scratches made in an attempt to learn more of the supposed siphuncle.

#### 4. *Ellesmeroceras scheii* Gen et. Sp. nov.

*Plate XXVII, figs. 3 A, B, C; Plate XXXIII, fig. 3*

Conch straight along the ventral side and presumably straight also along the dorsal side as far as may be determined from the specimen at hand. Apical angle small, probably about 8 degrees in a dorso-ventral direction. Conch compressed laterally. At the base of the living chamber the dorso-ventral diameter is estimated at 12 mm.; the lateral diameter is 10.5 mm.

The number of camerae in a length equal to the dorso-ventral diameter of the conch at the top of the series of camerae being counted is 10. Since the uppermost camera has about the same length as the camerae immediately beneath, it is not certain that the conch is mature. The sutures of the septa slope from the siphuncle along the median line of the ventral side downward toward the dorsal side, curving in a slightly sigmoid manner. Along the middle of the lateral sides of the conch the sutures form an angle of about 80 degrees with the vertical axis; toward the siphuncle the sutures rise more rapidly and toward the dorsal side of the conch they descend more rapidly than along the middle of the lateral sides.

The siphuncle is narrow and is in contact with the ventral wall of the conch; apparently it is slightly flattened by its contact with the latter. At the base of the specimen, where the diameter of the conch is estimated at 9 mm., the diameter of the siphuncle is about 1.4 mm. in a lateral direction. Laterally the segments of the siphuncle present slightly concave vertical outlines. If these segments represent downward continuations of the septal necks, then the latter descend the length of a single camera and they invaginate into the top of the septal necks next beneath. No trace of surface ornamentation is preserved.

Locality and Horizon.—From the *Orthoceras* limestone at Victoria Head on Bache peninsula, on Ellesmereland, west of Smith Sound. Regarded as of Canadian age. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Per Schei in May, 1899.

Remarks.—The species here described as *Ellesmeroceras scheii* has about the same apical angle as *Endoceras montrealense* (Billings) as figured by Ruedemann (Bull. New York State Museum, 1906, p. 424, pl. 9, fig. 8); the number of its camerae is also about the same, but in the latter species the sutures of the septa curve distinctly downward on approaching the siphuncle along the median part of the ventral side of the conch, and the relative size of the siphuncle is much greater.

In the upward curvature of the sutures of the septa on approaching the siphuncle *Ellesmeroceras scheii* resembles *Eremoceras syphax* but the apical angle of the latter is much greater, its form is slightly cyrtoceraconic due chiefly to lengthwise curvature along the dorsal side, and the siphuncle is much larger, tapers much more rapidly toward its apical end, and is appressed for a greater part of its width against the ventral wall of the conch.

*Ellesmeroceras* is regarded as a straight Endoceratitic shell with a relatively small siphuncle; the sutures rise on approaching the siphuncle, and the latter is in contact with the ventral wall of the conch. In true *Endoceras* the sutures do not rise in a conspicuous manner on approaching the siphuncle but are more nearly directly transverse. While I am doubtful as to the gen-

eric value of the differences noted above, the Ellesmereland specimen here described does not appear to me to be a typical *Endoceras*; the absence of any trace of *endocones* is certainly generic, if constant; hence the new generic term *Ellesmeroceras*, with *Ellesmeroceras scheii* as the genotype is here proposed.

Conchs with siphuncles in contact with the ventral wall are fairly common in the Canadian strata of eastern Canada and in the adjacent parts of the United States. Most of these forms are smooth but some are annulated. Most species are straight but curved forms also occur. Among smooth forms with relatively small siphuncles may be mentioned the species described by Billings as *Orthoceras cato*, *O. repens*, and *O. perseus*. The latter is laterally compressed. *Orthoceras sordidum* may belong here also. In *Orthoceras autolycus* the conch is slightly curved lengthwise.

Conchs with siphuncles in contact with the ventral wall occur also in the Ozarkian but most of these are more or less distinctly curved lengthwise.

The number of these early cephalopods in which the segments of the siphuncle show concave lateral outlines also is of interest. This type of outline is noted in *Eremoceras syphax* and *Ellesmeroceras scheii*. It is seen also in *Cyclostomiceras cassinense* (Whitfield). It is figured by Ruedemann in *Orygoceras cornuoryx* (Whitfield), *Protocycloceras whitfieldi* Ruedemann, and *Endoceras montrealense* (Billings). It was noted by Billings in the species described by him as *Orthoceras menelaus*, *Orthoceras indegator*, and *Orthoceras flavius*, the last two of which have the siphuncle in contact with the ventral wall, as in *Endoceras montrealense*. The number of such Canadian and Ozarkian cephalopoda with siphuncular segments presenting vertical lateral outlines is considerably multiplied if cyrtoceraconic forms be included. This type of outline appears to occur chiefly in Holochoanitic forms, but a reëxamination of all forms having this type of siphuncle is necessary.

As far as can be determined from the preceding observations, the occurrence of *Clarkoceras holtedahli* and *Ellesmeroceras scheii* in the *Orthoceras* limestone at Victoria Head suggests that this limestone includes a horizon of Canadian age.

Holtedahl, in his paper on "The Cambro-Ordovician Beds of Bache Peninsula," figures fossils from three horizons. From the sandstones at Cape Camperdown, at the southeastern corner of Bache peninsula, he figures a cranidium, a free cheek, and a pygidium of *Ptychoparia*. From an overlying light greyish-white limestone which crops out midway up the vertical face of Victoria Head he figures a cranidium of *Illaenurus* and one of *Ptychoparia*. From an overlying close-grained brown limestone farther up the Head he figures a pygidium of *Bathyriscus*, a *Maclurea*, and a *Hormotoma*. The *Clarkoceras* and *Ellesmeroceras* here described were obtained somewhere within the greyish-white limestone mentioned above. Since the total thickness of the latter was estimated by Per Schei at 350 feet, it is possible that more than one horizon here is included. The *Illaenurus* and *Ptychoparia* figured by Holtedahl suggest the Ozarkian age of the including strata, while the cephalopods here discussed suggest Canadian age. It is possible that both horizons are present in the greyish-white limestone at Victoria Head.

#### 5. *Protocycloceras lamarcki* (Billings).

*Plate XXXIII, figs. 7 A, B, C, D*

*Orthoceras lamarcki* Billings, Canadian Nat. Geol., 4, 1859, p. 362; Geol. Canada, Geol. Surv. Canada, 1863, p. 121, figs. 38 a, b, c; Pal. Foss. 1, Geol. Surv. Canada, 1865, pp. 255, 347, fig. 336.

*Protocycloceras lamarcki* Hyatt, Zittel-Eastman Textb. Pal. 1, 1900, p. 518; Ruedemann, Bull. New York State Mus., 90, 1906, p. 441, pl. 15, figs. 1-6; pl. 16, figs. 1, 2; figs. 15, 16.

Types.—The first published figure consists of three views of a specimen numbered 550 in the collections of the Geological Survey of Canada, and labelled as coming from lot 12, concession 12, Godmanchester township, in Huntingdon county, Quebec. This specimen is 36 mm. long and has 12 annulations in a length of 33 mm.; the diameter at its upper end is 17 mm.; and its apical angle is about 8 degrees. In preparing the first published figure a mirror camera lucida was used so that in both

figure 38a and figure 38b the direction of lengthwise curvature is opposite to that of the specimen itself. The latter consists of part of a phragmacone, exposing on one side the septa, which are only moderately concave. The sutures occupy the grooves between the annulations, the latter occurring at mid-height of the camerae. The siphuncle is relatively large, having a diameter of 6 mm. at the top of the specimen, where the diameter of the conch is 17 mm.

The second specimen figured by Billings, numbered 7455a in the collections of the Geological Survey of Canada, was obtained in Oxford township, in Greenville county, Quebec. In a length of 57 mm. it contains 20 annulations. The diameter at the top of the specimen is 18 mm.; here the diameter of the siphuncle is 7.2 mm.; and the center of the siphuncle is 8 mm. from the nearest wall of the conch, so that its location is only slightly excentric. In specimen 7456b, from the same locality, the center of the siphuncle is four-elevenths of the diameter of the conch from its nearest wall, thus indicating a greater amount of excentricity. Specimen 7456 consists of a phragmacone 110 mm. long, with an estimated diameter of 23 at the larger end. Full grown specimens probably attained diameters of at least 30 mm.

Specimen 550b, from the same locality as the first figured specimen, apparently has funnels descending for at least the depth of one camera.

Specimens 508 and 508a, from Romaine on the Gulf of St. Lawrence, apparently indicate obscurely that the lower end of each funnel is inserted for a short distance into the top of the funnel next beneath.

Locality and Horizon.—Found in various counties in the eastern part of the province of Quebec, and on the Mingan islands and on Newfoundland, in the Canadian formation. Also in the Beekmantown of New York.

## 6. *Protocycloceras whitfieldi* Ruedemann

*Plate XXXIII, fig. 4*

*Orthoceras bilineatum*, Whitfield; Bull. Amer. Mus. Nat. Hist., 3, 1890, p. 35, pl. 2, fig. 5, fig. 17 *a, b*.

*Protocycloceras whitfieldi* Ruedemann, Bull. New York State Mus. Nat. Hist., 90, 1906, p. 443, fig. 17*a*, pl. 15, fig. 7.

In a specimen of *Protocycloceras whitfieldi* Ruedemann, from the Fort Cassin beds at Fort Cassin, Vermont, the structure of the siphuncle is more distinctly shown. At the septal neck of the funnel, the latter bends abruptly downward; the funnel contracts downward in one specimen from a diameter of 7 mm. at the neck to 6.3 mm. a little below the middle of the camera beneath, expanding to 6.5 mm. at its lower margin, which descends for a distance equalling about one-fourth of the height of a camera into the upper part of the funnel next beneath. In longitudinal sections, the siphuncle appears broadly annulated at the septa, with very shallow intermediate grooves which have their maxima of contraction slightly beneath mid-height of the camerae. No distinct markings were noticed on the surface of either *Protocycloceras whitfieldi* or of *Protocycloceras lamarchi*.

## 7. *Protocycloceras* cf. *lamarchi* (Billings)

*Plate XXVII, fig. 5; Plate XXXIII, fig. 5A, B*

*Orthoceras* ? sp., Hortedahl, Paleozoic Series of Bear Island, 1919, p. 129, pl. 13, fig. 1.

Conch enlarging very slowly, from 13.3 mm. to 14.6 mm. in a length of 18 mm. The lower 4 camerae occupy a length of 10 mm.; and the upper 5 camerae, of 14 mm. The sutures are assumed to have been directly transverse though they are not exposed for a sufficient distance around the circumference of the conch to permit the determination of their course with exactness. The septa are moderately concave, curving downward a distance of 2 mm. where their diameter is 14 mm. The siphuncle is relatively large, being 5 mm. in diameter where the diameter of the conch is 14.5 mm. The position of the siphuncle

is nearly central, one side being 4.5 mm. from the nearest wall of the conch while the other side is 5 mm. distant from the opposite wall. Within each camera the enclosed segment of the siphuncle appears to become narrower in a downward direction, curving slightly inward so as to present slightly concave vertical outlines. Apparently the lower margin of each segment of the siphuncle invaginates into the top of the septal neck next beneath. Apparently also the surface of the shell is slightly annulated, the crests of the annulations coinciding with mid-height of the camerae.

Locality and Horizon.—Collected 1 kilometer west of Norsk-havna, or 1.4 kilometers north-north-west of the northern margin of South Harbor on Bear Island, July 1918, by Olaf Holtedahl. In the Palaeontologisk Museum, Kristiania, Norway. Original of Fig. 1 on plate II of Holtedahl's paper on the Paleozoic Systems of Bear Island. From the younger dolomite series, in the Hecla-hook System of strata, corresponding to the Canadian of North America.

Remarks.—The specimen from Bear Island is too poorly preserved for exact determination, but its annulation, though slight, and its large subcentral siphuncle with segments narrowing in a downward direction suggest affinities with *Protocycloceras lamarcki*. At least the resemblance is sufficient to suggest the Canadian age of the enclosing strata on Bear Island. The original identification of these Bear Island strata as Canadian was based by Holtedahl on the association in the same strata of such characteristic genera as *Calathium*, *Archaeoscyphia*, and *Piloceras*. The Bear Island *Calathium* resembles *Calathium pannosum* Billings, an Ozarkian species from Point Levis, Quebec, and the *Piloceras* is closely related to *Piloceras explanator* Whitfield from the Beekmantown member of the Canadian in Vermont and New York. *Archaeoscyphia* is listed from the Canadian of the Mingan Islands, in Canada.

8. *Deltoceras* (?) sp.

*Plate XXVII, fig. 6; Plate XXXIII, figs. 6A, B, C*

Cyrtoceraconic shell of uncertain genus, Høltedahl, Paleozoic Series of Bear Island, 1919, p. 130, p. 13, fig. 2.

Nautiloid shell, with volutions strongly compressed laterally, the dorso-ventral diameter of the specimen being 33 mm.; and the lateral diameter 20 mm. The siphuncle is cylindrical in form and slightly over 3 mm. in diameter; its center is 5.5 mm. from the ventral wall of the volution. That part of the siphuncle which is exposed in the specimen is crossed at mid-length by a single complete septum having a concave curvature of about 7 mm. The ventral fourth of another septum is preserved 10 mm. from the first septum, on its orad side. Owing to the angle at which this part of the specimen has been cut, the passage of the siphuncle through this second septum is not retained. A third septum is exposed on the apical side of the first mentioned septum, at a distance of 11 mm. from the latter. This third septum is the one exposed in the figure presented by Høltedahl, cited above. Judging from the small curvature of the siphuncle and of the ventral wall of the specimen at hand, the complete phragmacone could easily have equalled 150 mm. in diameter measured across the volutions, and the complete shell probably was considerably larger.

From the curvature of the septum at the apical end of the specimen it is evident that the sutures of the septa had broad lateral lobes and also dorsal and ventral saddles; the general appearance of the saddles must have been affected by the strong lateral compression of the conch. It can not be determined definitely from the small fragment at hand whether the specimen was transversely ribbed or not, but it is assumed that no pronounced ribbing was present. Moreover, there is no evidence of an impressed zone along the dorsal side of the specimen due to contact with the ventral side of preceding volutions.

Locality and Horizon.—Collected 1 kilometer west of Norsk-havna, or 1.4 kilometers NNW of the northern margin of South Harbor, on Bear Island, by Olaf Høltedahl, in July, 1918. Depos-

ited in the Palaeontologisk Museum at Kristiania. Original of fig. 2 on plate 13 of Høltedahl's paper, cited above. From the younger Dolomite series, in the Hecla Hook System of strata, corresponding to the Canadian of North America.

From such a small fragment it is impossible to determine with confidence the generic relationship of this species, but it evidently belongs to the *Tarphyceratidae*.

#### 9. *Kionoceras laqueatum* (Hall)

*Orthoceras laqueatum* Hall, Pal. New York, 1, 1847, p. 13, pl. 3, fig. 12.

Type.—Apical angle about 9 degrees. Diameter at the top of the specimen estimated at 9 mm. In a letter Dr. Ruedemann states regarding this specimen that "The *Orthoceras laqueatum* shows 11 vertical ribs on the visible half. Since that is not quite the entire half, I should judge there were 20 ribs on the shell. There is always one stria between two ribs." Nothing is known of its interior structure.

Locality and Horizon.—From some unknown locality in the Beekmantown division of the Canadian in New York state. Hall stated that "the position of the specimen is probably at the upper termination of this (Beekmantown) rock, and just at its passage into the succeeding limestone." The type is numbered 12375 in the New York State Museum of Natural History at Albany, New York.

Remarks.—The reference of this specimen to *Kionoceras* must be regarded as tentative. If *Kionoceras* arose from a multistriate ancestral *Orthoceroid* by the increased prominence of certain of the vertical striae, then *Orthoceras laqueatum* may be regarded as ancestral to typical *Kionoceras*.

#### 10. *Kionoceras holtedahli* Sp. nov.

*Orthoceras* (*Kionoceras*?) sp. Høltedahl, Ordovician Fossils from Bear Island, 1918, p. 84, pl. 11, fig. 2.

Judging from the figure published by Høltedahl, the apical angle of the conch is about 4.5 degrees, and the number of verti-

cal ribs is somewhere near 32; about 4 camerae appear to occupy a length equal to the diameter of the conch at the top of the series of camerae being counted, but Høltedahl states that the distance between the septa is one-fifth of the diameter of the shell. The vertical section of the lower end of the specimen, as figured by Høltedahl, indicates that the segments of the siphuncle are almost globular, that the diameter of the siphuncle equals almost one-fourth of that of the conch, and that its center is about one-third of the diameter of the conch from its ventral wall. In describing the ornamentation on the surface of the shell Høltedahl states that the "longitudinal ridges, though not much elevated, have a rather sharp section. In some places there seems to be present a faint ridge in the middle of the interval between the ridges and possibly an indication of other, extremely faint ones."

Locality and Horizon.—From the Antarctic Mountain area in the southern part of Bear Island. From the *Tetradium* limestone at the top of the Heclahook system. This limestone is regarded as of Black River age. In the Riksmuseet, Stockholm, Sweden.

Remarks.—At least two undoubted specimens of *Kionoceras* occur in strata below the Richmond in American areas, namely *Kionoceras kentlandense* from the Black River area in north-western Indiana and a lower Trenton form from New York described by Hall under *Orthoceras laqueatum* ? var. *a*. Three other species, typical *Orthoceras laqueatum* from the Beekmantown of New York, a similar species from the Leray at Pauquette Rapids, Canada, and the specimen here described as *Kionoceras trentonense* from the middle Trenton at Middleville, New York, may belong to the vertically striated forms from which *Kionoceras* originated. Foord refers to *Orthoceras laqueatum* some imperfectly preserved specimens from the Trenton at Montmorenci Falls, near Quebec, Canada which show "traces of what would appear to have been longitudinal ridges." It is cited also from the Trenton at Frobisher Bay, on Baffin Land.

11. *Kionoceras trentonense* Sp. nov.*Plate XXXV, fig. 1*

*Orthoceras laqueatum* (Hall), Pal. New York, 1, 1847, p. 206, pl. 56, figs. 2 b, c.

Apical angle about 3 degrees. Diameter at top of specimen estimated at 5 mm. Length of specimen 22 mm. At the smaller end of the specimen a septum terminates the specimen. That part of the specimen which in Hall's figure extended beneath this septum consisted of nothing but matrix. The siphuncle, at its passage through the septum, is small and slightly excentric in position. The surface of the shell is occupied by about 20 primary vertical ribs and an equal number of almost equally prominent secondary riblets which alternate with the primary ones. Both ribs and riblets rise acutely above the general surface of the shell. In the grooves between the ribs and riblets there are additional and much finer striae, usually 3, sometimes 4 or 5 in number, and visible only under a lens. Finally, the microscope reveals numerous very fine transverse striae, about 70 in a length of 1 mm. These striae are horizontal along the left third of the exposed part of the shell, they curve rather strongly downward along the middle third and become horizontal again along the right third. It is assumed that the right third of the exposed part of the shell is the ventral side, and that there was a distinct hyponomic sinus whose depth is indicated by the amount of deflection of the transverse striae.

Locality and Horizon.—According to Hall this specimen is from the middle portion of the Trenton at Middleville, New York. The specimen is numbered 802 A in the American Museum of Natural History in New York city.

Remarks.—The Trenton species here described differs from typical *Orthoceras laqueatum* from the Beekmantown in its much smaller apical angle. It is probable that if more were known of the surface markings and internal structure of both forms that other differences would be noted.

A similar specimen, from the Leray member of the Lowville at Pauquette Rapids in Ontario, has 3 camerae in a length

equal to the diameter of the conch, where the latter is 10 mm. At this point the diameter of the siphuncle is 1 mm., and its distance from the dorsal side of the conch is 3.7 mm. The form of the siphuncle is tubular, not enlarging within the camerae. The conch is slightly curved lengthwise, with the dorsal side concave. There are about 40 vertical striae, more or less alternating in size.

Vertically ribbed Orthoceroids of the *Orthoceras laqueatum* type occur also in the Bala beds of Great Britain, where they are known as *Orthoceras lineatum* Hisinger. *Orthoceras striatum* Mareklin, *Orthoceras subcostatum* Portlock, and *Orthoceras striatopunctatum* M'Coy are other terms whose exact value will be understood only after the types have been fully illustrated and described.

## 12. *Kionoceras* Sp.

### *Plate XXXV, fig. 2*

*Orthoceras laqueatum* ? var. *a* Hall, Pal. New York, 1, 1847, p. 206, pl. 56, fig. 3.

Specimen 22 mm. long, 7 mm. wide at the base of the specimen and 8 mm. wide at its top, with an apical angle of about 3.5 degrees in a lateral direction. Cross-section elliptical, the diameters at the base being 7 and 4.5 mm. respectively. There is no trace of septa or siphuncle; the specimen therefore may consist of most of a living chamber. The surface of the specimen is marked by 20 vertical ribs, each about a quarter of a millimeter in width, the intervening grooves being three-quarters of a millimeter wide. The crest of the ribs is angular, and the elevation of the ribs is conspicuous, considering the small size of the specimen. The crests of the ribs are crossed by transverse striae, about 13 in a length of 5 mm., but no trace of these striae is noticed in the broad intermediate grooves. Possibly the striation is structural and within the substance of the shell rather than on its surface.

Locality and Horizon.—From the lower shaly strata of the Trenton at Middleville, New York. The matrix of the specimen contains a brachial valve of *Triplecia nucleus* (Hall). The

specimen is numbered 802 B in the American Museum of Natural History in New York city.

Remarks.—The general aspect of the shell with its prominent ribs and broad intermediate grooves is so similar to that of *Kionoceras* that the generic reference may be assumed to be correct. Compared with *Kionoceras kentlandense* Kindle and Breger, from the Black River of northwestern Indiana, the number of vertical ribs is only 2 or 3 less, their number in the Indiana species being 22 or 23. It is probable that the New York Trenton species is distinct from the Indiana Black River form, but in case of the former the interior structure is unknown and in case of the latter the surface features are not preserved.

A specimen similar to the New York species in the number and prominence of its vertical ribs occurs in the Leray member of the Lowville at Pauquette Rapids, in Ontario. There are 22 ribs, and the cross-section is cylindrical. It is 21 mm. long, and enlarges from 3.6 mm. to 4.7 mm. in this length. The siphuncle is half a millimeter in diameter, and its position is almost central.

### 13. *Kionoceras kentlandense* (Kindle and Breger)

*Orthoceras* (*Kionoceras*) *kentlandensis* Kindle and Breger, 28th Ann. Rep. Dep. Geol. Nat. Res. Indiana, 1904, p. 470, pl. 21, fig. 2.

Type.—The specimen enlarges from 7 mm. at the lower end to 11 mm. at the upper end, the interval being 78 mm., suggesting an apical angle of 3 degrees. Only the cast of the interior of the conch is at hand. This is marked by 22 or 23 vertical ribs which are distinct, though low, along the entire length of the specimen, including the living chamber. At the top of the phragmacone there is a series of 6 camerae successively shorter in length, indicating that the specimen had attained maturity; all 6 of these camerae occupy a total length equal to only ten-ninths of the diameter of the conch. Of the living chamber a length of 17 mm. remains, but this does not include the upper part of the living chamber which, in this genus, should

show a contraction along the upper part of the cast of the interior, a short distance below the aperture. The siphuncle is about 1.25 mm. in diameter at the base of the specimen and its location is somewhat excentric. No trace of the surface markings, beyond the presence of vertical ribs, is present in this type.

Locality and Horizon.—The type is numbered 685 in the State Museum of Indiana, at Indianapolis, Indiana. It occurs in a very fine-grained, brownish-gray limestone having a conchoidal fracture, resembling some phases of the Plattin limestone of eastern Missouri. The same limestone, at Kentland, Indiana, contains *Columnaria halli*, *Rafinesquina minnesotensis*, *Strophomena trentonensis*, *Zygospira recurvirostris*, *Ctenodonta nasuta*, *Actinoceras beloitense*, *Isotelus* cf. *platycephalus*, and *Thaleops ovatus*. This is a typical representative of that fauna in the upper Mississippi Valley which is correlated with the Black River limestone of New York.

#### 14. *Leurorthoceras hanseni* Gen. et Sp. nov.

*Plate XXX, figs. 1A, 1B; pl. XXXI, fig. 1; pl. XXXII, fig. 8; pl. XXXIV, fig. 2*

Specimen consisting of part of a phragmacone having an apical angle of 14 degrees in a lateral direction and of 4 or 5 degrees in a dorso-ventral direction. The cross-section of the conch is subtriangular. This subtriangular outline is produced chiefly by the strong and broad flattening of the ventral side of the conch and the strong transverse curvature of the shell along its ventro-lateral angles. Along the dorsal half of the conch the transverse curvature is fairly regularly convex, that of the smaller end of the specimen corresponding fairly well to the curvature of a circle 45 mm. in diameter. The dorso-ventral diameter at this smaller end equals 30 mm.

In a length equal to the lateral diameter of the conch there are 6.5 camerae. Along the dorsal half of the conch the sutures are directly transverse, but along the ventral half they curve distinctly downward. At the upper end of the specimen the amount of this downward curvature equals 5 mm. Along the

median part of the shell the curvature of the sutures is evenly concave, but toward the lateral sides they tend to diverge at angles of 155 to 158 degrees. The curvature of these sutures corresponds approximately to that which would result if a normal cylindrico-conical Orthoceroid had one side ground away until a similar subtriangular cross-section were produced. The sutures curve downward a distance of 6 or 7 mm., reaching their lowest level about 7 mm. dorsad of the center of the siphuncle. At the lower end of the specimen where the dorso-ventral diameter of the conch is 30 mm., the narrowest part of the septal necks is slightly less than 5 mm. in diameter. The length of these septal necks is 2 mm. and at their lower margins they curve distinctly outward. Within the camerae the segments of the siphuncle attain a maximum diameter of 9.5 mm. In vertical sections the outlines of these segments tend to be circular rather than broadly nummulitic, at least along the lower part of the specimen. The shell material of the siphuncle appears to have been extremely thin, and only parts of the connecting rings are distinctly preserved, in some camerae more than in others.

No indication of surface markings is retained by the specimen, which is a cast of the interior of the conch.

Locality and Horizon.—From some unknown locality either on Boothia Felix or on King William Land; probably from Black River limestone. In the Palaeontologisk Museum, Kristiania, Norway. Collected in 1903-04 by Lieut. Godfred Hansen in whose honor this species is named.

Remarks.—*Leurorthoceras hansenii* is very similar to *Leurorthoceras chidleyense*, described in this paper, from which it differs in having a smaller apical angle; it is less strongly flattened ventrally, and the segments of the siphuncle are relatively narrower. Both species are congeneric and both are regarded as belonging to a new genus for which the term *Leurorthoceras* is proposed, with *Leurorthoceras hansenii* as the genotype. This is characterized by the flattening of the ventral side of the conch, the broad ventral lobes of the sutures, and the relatively moderate inflation of the segments of the camerae compared with strongly nummulitic forms like *Actinoceras*.

Unfortunately the age of neither *Leurorthoceras hanseni* nor of *Leurorthoceras childleyense* is fully established. In both cases the type specimens occur associated with other specimens of undoubted Black River age, but in each case the *Leurorthoceras* in question consists of a matrix differing lithologically from that of the associated Black River fossils sufficiently to admit of the possibility of the former belonging to a different geological horizon.

Orthoceroids with flattened ventral sides are known also from other localities and horizons but are not known to have the same structural characteristics of the siphuncle as in *Leurorthoceras*.

In *Orthoceras capitulinum* Safford, from the Bigby member of the Trenton at Nashville, Tennessee, according to the figures presented by Safford, the lateral angles of this species are even more angular than those of *Leurorthoceras hanseni*. About 15.5 camerae occupy a length equal to the lateral diameter of the conch at the top of the series of camerae being counted. At the base of the specimen the lateral diameter is 62 mm., the dorso-ventral one is 38 mm., the diameter of the siphuncle at its passage through the septum is 15 mm., and the distance of this siphuncle from the ventral wall of the conch is about half a millimeter. It is difficult to conceive how there could be room here for a strongly nummuloidal siphuncle. I am informed by Prof. L. C. Glenn that the type of *Orthoceras capitulinum* can not be found in the Safford collection at Nashville, Tennessee, and probably has been lost.

Specimens in the U. S. National Museum, identified as *Actinoceras capitulinum*, have undoubted nummulitic siphuncles, 15 to 20 mm. in diameter, in direct contact with the ventral wall of the conch, but not enough of the circumference of the conch is preserved to show the subtriangular cross-section.

In *Orthoceras murrayi* Billings, from the Black River limestone on St. Joseph Island, Lake Huron, the cross-section is more triangular than in any of the species discussed so far. This triangularity is due not only to the flattening of the ventral side of the conch but also to the flattening of the two dorso-ventral sides, producing a distinct line of angularity along the median

part of the dorsal side. Where the lateral diameter of the conch is 40 mm., the dorso-ventral diameter is 30 mm., the passage of the siphuncle through the septa scarcely equals 6 mm., and the distance of this siphuncle from the ventral wall is 2.5 mm. In form, the siphuncle is tubular, not enlarging between the septa. This is at variance with the structure of either *Leurorthoceras* or of *Orthoceras capitulinum*. Along the median part of the dorsal side the sutures curve distinctly upward.

In *Tripleuroceras robsoni* Whiteaves, from Stonewall, Manitoba, and regarded by Whiteaves as Niagaran, the ventral side again is flattened, and the sutures of the septa curve downward here as in *Leurorthoceras*. Moreover, Whiteaves states that in the Manitoba species the sutures are "nearly straight where they pass over the sides." If the term *straight* here is equivalent to *horizontal* then the general appearance of the sutures in this species should be similar to that in *Leurorthoceras* also dorsally. In regard to the siphuncle of the Manitoba species, however, Whiteaves states that "it would have been better to say, that its exact shape, size and relative position are not at all clearly shown in the few specimens yet collected, though it seems to have been marginal and enlarged between the septa." Judging from one of the figures accompanying Whiteaves's description of the Manitoba species, the siphuncle of the latter must have been large and different in character from *Leurorthoceras*.

In typical *Tripleuroceras*, founded by Hyatt on *Orthoceras archiaci* Barrande, from the Silurian of Bohemia, the cross-section of the conch is very similar to that of *Leurorthoceras* but the siphuncle is almost in contact with the ventral wall of the conch, its segments are distinctly nummuloidal, and the interior of the siphuncle is filled by vertical radiating plate-like deposits. Whether *Tripleuroceras robsoni* has the same type of structure remains to be determined.

In the Silurian genus *Mixosiphonoceras*, founded by Hyatt on *Cyrtoceras desolatum* Barrande, from the Silurian of Bohemia, the cross-section of the conch is triangular, but the siphuncle is situated not close to a flattened ventral side but near the unpaired angle of the triangle. Without a knowledge of the

location of the hyponomic sinus in this species it is impossible to determine with confidence whether this unpaired angle represents the ventral or the dorsal side of the conch, but in either event the siphuncle of *Mixosiphonoceras* at least appears to occupy a position directly opposite to that in the species previously discussed. Moreover, in *Mixosiphonoceras* the conch is curved lengthwise, the siphuncle being located near the concavely curved side; the segments of the siphuncle enlarge only moderately within the camerae, and the interior of the latter is occupied by vertical radiating plate-like deposits.

In the Devonian genus *Jovellania*, founded by Bayle on *Orthoceras buchi* de Verneuil, from Nehon (Manche), France, the conch is annulated and its cross-section is only slightly triangular, due to a slight flattening of the ventro-lateral sides of the conch, causing the median part of the ventral side to be slightly angulated. There is no corresponding flattening of the opposite or dorsal side of the conch. The siphuncle is located near the angulated median part of the ventral side. Where the dorso-ventral diameter is 25 mm. the center of the siphuncle is 6 mm. from the ventral angle. The segments of the siphuncle enlarge only moderately within the camerae and the interior of the latter is occupied by vertical radiating plate-like deposits.

Compared with typical *Jovellania*, *Orthoceras murrayi* is not annulated; the siphuncle is located near the strongly flattened ventral side of the conch; the form of this siphuncle is tubular instead of moniliform, and the interior of this siphuncle is not filled with radiating vertical plate-like deposits.

#### 15. *Leurorthoceras chidleyense* Sp. nov.

*Plate XXXIV, figs. 1 A, B, C, D*

Lateral apical angle 11 degrees. Ventral side gently convex or distinctly flattened along its median part; dorsal side much more strongly convex. At the lower end of the specimen, where its lateral diameter is 39 mm., the radius of transverse curvature of the ventral side is 20 mm., that of the dorsal side being 28 mm. At the top of the specimen, where its lateral diameter is

52 mm., the radius of transverse curvature of the ventral side is 50 mm., that of the dorsal side being estimated at 25 mm. At this larger end of the specimen the transverse curvature at the ventro-lateral angles has a radius of about 11 or 12 mm.

Five camerae occupy a length equal to the lateral diameter of the conch at the top of the series being counted. On the dorsal side, the sutures of the septa are directly transverse. On the ventral side these sutures curve downward, producing broad shallow lobes having a depth of 4 mm. at the base of the specimen, increasing to 5 mm. at its top. The lateral curvature of these ventral lobes increases from 30 mm. at the base of the specimen to 33 mm. at its top. The septum at the base of the specimen slopes downward from the dorsal side toward the ventral side at an angle of about 82 degrees with the vertical outline of the ventral side. In fact, the structure of the phragmacone is similar to that of an ordinary species of *Orthoceras* in which one side had been filed away so as to produce a similar flattened outline.

At its passage through the septum the siphuncle has a diameter of about 3 mm. The center of the siphuncle is slightly less than one-fourth of the dorso-ventral diameter of the conch from its ventral wall. The septal necks of the siphuncle are 2 mm. in length and curve outward toward their lower margin. The connecting rings, which join successive septal necks, are preserved only on the ventral side of the siphuncle, but originally these rings appear to have enlarged to a diameter of about 6 mm. within the camerae, producing segments of the siphuncle with vertically elliptical outlines as in *Loxoceras*.

No indications of surface markings are present, the specimen being a cast of the interior of the conch.

Locality and Horizon.—From blocks found loose at Port Burwell, twenty miles west of Cape Chidley, at the northern end of Labrador. Regarded as of Black River age on account of associated fossils, also loose. Collected by A. P. Low. Numbered 7923 in the collections of the Geological Survey of Canada.

16. *Actinoceras tenuifilum* (Hall.)

*Plate XXVIII, fig. 2; Plate XXXII, fig. 1*

*Ormoceras tenuifilum* Hall, Pal. New York, 1, 1847, p. 55, pl. 15, figs. 1, 1*a-c*; pl. 16, figs. 1, 1*a-e*; pl. 17, figs. 1, 1*a, b*.

Type specimen.—The specimen represented by fig. 1 on plate 15 of the publication cited above is regarded as the type of the species. Its apical angle is 12 degrees. According to figure 1*a* on plate 16, 6 camerae occupy a length equal to the diameter of the conch at the top of the series being counted, at the smaller end of this type. The siphuncle is large. According to figure 1*a* on plate 15, it is submarginal in position. In reply to an inquiry regarding the vertical striae illustrated by Hall in figure 1 and again in figure 1*b* on plate 15, Dr. Ruedemann states in a letter:

The surface marking on specimen figure 1 is microscopic, but very sharp and distinct. There are about 7–10 unequal striae to 1 mm. Your assumption that they belong to an interior coat is probably right, for there is a smooth patch over them at the upper end of the conch. Besides these longitudinal lines there is in one place also a system of fine transversal lines. The latter probably belong to the surface and have been projected upon the lower layer when the outer layer was dissolved.

Cotypes.—In the specimen represented by figure 1*c* on plate 15, the apical angle is 11 or 12 degrees. Along the smaller part of the specimen 6.5 camerae occupy a length equal to the diameter of the conch, increasing to 7 camerae toward the larger end. About 90 mm. above the smaller end, the diameter of the specimen is 46 mm., that of the siphuncle is 24 mm., and the latter is about 2 mm. from the ventral wall of the conch. The surface of the shell is smooth.

In specimen 1*b* on plate 16, the margin of the siphuncle is within 1 or 2 mm. of the ventral wall of the conch; 6 or 7 camerae occupy a length equal to the diameter of the conch. In specimen 1*c* on the same plate the siphuncle again is submarginal, and the surface of the shell is smooth. The present location of

specimen 1d is unknown. In specimen 1e the siphuncle is submarginal in position; 5 camerae occupy a length equal to the diameter of the conch at the smaller end of the specimen, increasing to 5.5 camerae at the larger end; the surface of the shell is smooth.

In specimen 1 on plate 17, the siphuncle is between 1 and 2 mm. from the ventral wall of the conch; the surface of the shell appears to have been smooth; and, judging from the curvature of the small part preserved, the dorso-ventral diameter was distinctly shorter than the lateral one. In specimen 1b, the siphuncle again is submarginal in position. In specimen 2, the type of the variety *distans*, 4 camerae occur in a length equal to the diameter of the conch at the lower end of the specimen, increasing to 5 camerae in the second fifth of the length of the specimen above its base, to 5.5 camerae near mid-length, and to 6 camerae near its top; the siphuncle is within 1 or 2 mm. from the ventral wall of the conch.

Specimens 2a and 2b on plate 58 were originally figured among Trenton species, although doubt was cast upon their occurrence in the Trenton. The matrix resembles that of typical Black River specimens from the Watertown area. Dr. Ruedemann states in a letter:

I do not remember ever having seen an *Actinoceras tenuifilum* in the Trenton. It is quite common both in the Watertown and Leray limestones. Some specimens have been noticed in the Lowville (see Bull. 145, New York State Mus., p. 841 footnote); Dr. Ulrich claimed at the time that these should be a different species, but none were collected.

In specimen 2a mentioned above, the location of the siphuncle is submarginal, and the surface of the conch, as far as known, is smooth. In specimen 2b, the apical angle is 12 degrees. At the lower end of the specimen the diameter of the conch is 30 mm. and that of the siphuncle is 19 mm.; at the upper end, the diameter of the conch is about 51 mm. laterally, that of the siphuncle being 26 mm.; judging from the curvature of the part preserved, the shell was slightly depressed dorso-ventrally. At the bottom of the specimen 6 camerae occupy a length equal to

the diameter of the conch, increasing to 7 camerae toward the larger end of the specimen. The surface of the shell is chiefly smooth, but 2 or 3 mm. below the sutures of the septa there is in several places a transverse ridge curving downward with the sutures on the ventral side of the conch, so as to suggest the former presence of a hyponomic sinus. The amount of this downward curvature is at least 5 mm. near the larger end of the specimen. It is approximately commensurate to that of the *Actinoceras* from the Boothia Felix-King William Land area, represented in this paper by figure 2 on Plate XXX.

Figured specimen.—Figure 2 on Plate XXVIII of this paper represents a typical specimen of *Actinoceras tenuifilum* from the Black River at Watertown, New York. It is part of the duplicate material originally belonging to the New York State Museum of Natural History, and was presented to the writer by Dr. Rudolf Ruedemann. About 5 camerae occupy a length equal to the diameter of the conch at the smaller end of the specimen, increasing to 5.5 camerae at its upper end. The diameter of the siphuncle equals about 64 per cent of that of the conch, and its margin is within 1 mm. of the ventral wall of the latter. The septa are strongly concave. The septal necks descend slightly over 2 mm. below the general concave curvature of the septa, and the distance between successive annulations of the siphuncle equals or slightly exceeds 2 mm. The septa are in contact with the lower surface of these annulations. Toward the larger end of the specimen, the annulations of the siphuncle decrease in size as in *Paractinoceras*. The sutures curve downward toward the median part of the ventral side a distance of 4 or 5 mm. At the base of the siphuncle, its axial part, for a diameter of about 2 mm., is free from organic deposits, being filled with black matrix. Toward the top of the siphuncle this axial part free of organic deposits increases more or less irregularly to 5 mm. in diameter, indicating progressive deposition of organic material with increasing age.

Resume.—In typical *Actinoceras tenuifilum* the conch is slight depressed dorso-ventrally, the apical angle is about 12 degrees; the number of camerae in a length equal to the diameter of the

conch usually varies between 5.5 and 6.5, but may be as low as 4 and as high as 7. The siphuncle is relatively large, equalling at least 55 to 60 per cent of the diameter of the conch at the lower end of the latter, though apparently diminishing in size toward its upper end as in *Paractinoceras*. The sutures of the septa curve moderately downward on the ventral side of the conch. The surface of the shell usually is smooth, but occasionally is striated or ribbed transversely in a direction more or less parallel to the sutures of the septa.

### 17. *Actinoceras* Sp.

*Plate XXX, figs. 2A, B; Plate XXXII, fig. 7*

The specimen consists of a fragment of a phragmacone 130 mm. in length, of which the lower part, beneath an oblique crack, is not figured. The specimen is strongly flattened on its dorsal and ventral sides, probably due to compression of the enclosing sediments previous to solidification. In my opinion this compression of the sediments resulted merely in a shortening of their vertical dimensions, and was not accompanied by any horizontal expansion, either of the sediments or of their contents. If this view be correct, then the present lateral apical angle of the specimen and its present width correspond closely to the original lateral dimensions of the specimen, though its dorso-ventral dimensions are greatly shortened.

In its present condition the lateral apical angle of the conch equals 10 degrees, and from 6 to 6.5 camerae occupy a length equal to the lateral diameter of the conch at the top of the series of camerae being counted. Along the dorsal side of the conch the sutures of the septa curve only slightly downward, possibly only 1 or 2 mm., and even this slight downward curvature may be due to compression. Along the ventral side, on the contrary, the downward curvature of the sutures is much more pronounced, equalling 7 mm. Most of this downward curvature appears to take place along the ventro-lateral parts of the conch, the downward curvature being much more moderate along the median parts of the ventral side of the conch. At the top of the speci-

men the lateral diameter of the siphuncle appears to be 30 mm. Below the oblique crack at the base of the figured part of the specimen there is an unfigured part showing distinctly the dorsal outlines of 3 segments of the siphuncle. As far as can be determined, the width of the siphuncle here is 32 mm. where the lateral diameter of the conch is 48 mm. Unfortunately it is impossible to determine with certainty whether the location of the siphuncle is central or marginal, although I am inclined to regard it as submarginal, extending to within 1 mm. of the ventral wall of the conch, and with its nummuloidal segments oblique to the vertical axis. The vertical outline of the segments of the siphuncle, the distance between consecutive annulations of the siphuncle, the length and curvature of the septal necks, the adnation of the septa to the lower side of the annulations, all are similar to those of *Actinoceras tenuifilum*.

The surface of the shell is marked by low and rather broad transverse striae which tend to be sub-parallel to the sutures of the septa, especially along the broad median parts of the ventral side of the conch; but ventro-laterally, where the sutures slope more rapidly downward, the course of the transverse striae is slightly less oblique than that of the sutures. At or immediately above the sutures one of the striations tends to be slightly more conspicuous.

Locality and Horizon.—From some unknown locality, probably of Black River age, either on Boothia Felix or on King William Land. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Lieut. Godfred Hansen in 1903-04.

Remarks.—The downward curvature of the sutures of the septa on the ventral side of this specimen probably is shared with all species in which the siphuncle is marginal or submarginal, though the degree and angularity of this downward deflection may vary in different species. It is regarded as related more nearly to *Actinoceras tenuifilum* than to any other described species, but a better knowledge of the siphuncle is needed in order to determine its relationship with some degree of confidence. It may be a new species but in the absence of definite knowledge of its siphuncle it can not serve as a type.

18. *Actinoceras amundseni* Sp. nov.

*Plate XXIX, figs. 1A, 1B; Plate XXXII, fig. 3*

Specimen exposing the ventral side of the cast of the interior of the phragmacone, including the sutures of the septa, and exhibiting also the dorsal side of the siphuncle.

The diameter of the conch, as far as can be determined from the transverse curvature of its ventral side, is estimated at 70 mm. Apparently there is a slight tendency toward angularity along the median part of this ventral side. It is estimated that 6 camerae occupy a length equal to the diameter of the conch. The sutures curve strongly downward on its ventral side, forming an angular ventral lobe or hyponomic sinus with sides diverging at an angle of 140 degrees. The septa are deeply concave.

The siphuncle is almost in contact with the ventral wall of the conch, being 1 or 2 mm. distant from the latter. The maximum diameter of the segments of the siphuncle is 28 mm., narrowing to 19 mm. at the grooves separating the segments. Where the height of the segments is 13 mm., the septa are adnate to the lower part of these segments for a height of 5 mm.; along this part of the segments the vertical outline of the latter is nearly straight or only faintly concave. Above the point of departure of the septa, the vertical outline of the segments is strongly convex, reaching its maximum 7 or 8 mm. above the base of the segments. The upper surface of the segments forms an angle of 105 or 110 degrees with the vertical axis of the conch, rising toward its ventral side. No trace of surface markings remains.

Locality and Horizon.—From some unknown locality, probably of Black River age, either on Boothia Felix or on Prince William Land. In the Palaeontologisk Museum, Kristiania. Collected in 1903-04 by Lieut. Godfred Hansen, on the expedition of the *Gjoa*, led by Captain Roald Amundsen, in whose honor this species is named.

Remarks.—In *Actinoceras amundseni* slightly more than 2 segments of the siphuncle occur in a length equal to the maximum diameter of these segments. This is true also of *Huron*

*obliqua* Stokes; in the type of *Huronia septata* Parks this number is exactly 2. The chief difference between *Huronia septata* and *Huronia obliqua* noted so far consists in the distinct obliquity of the upper surface of the segments of the siphuncle in the latter and in the almost directly transverse slope of this surface in the former species; thus indicating that the siphuncle of *Huronia obliqua* is strongly excentric in position while that of *Huronia septata* is nearly central. In this respect *Actinoceras amundseni* resembles *Huronia obliqua* more closely. However, in *Actinoceras amundseni* the tendency toward a concave lateral outline along the lower half of the segments of the siphuncle is much less conspicuous, and this difference is regarded as sufficient to indicate a new species. The rather angular downward deflection of the sutures of the septa along the median line of the ventral side of the conch may be another distinctive feature, although it is shared with *Actinoceras imbricatum* Hisinger, and I suspect that it is present also in other species in which the siphuncle is virtually in contact with the ventral wall of the conch.

To me the general aspect of *Actinoceras amundseni* and of *Huronia septata* is Silurian rather than Ordovician, but lithologically the type of *Actinoceras amundseni* resembles other specimens from the Boothia Felix-King William Land area regarded as of Black River age, and the type of *Huronia septata* was obtained at the Lower Rapids of the Shamattawa River, where the general assemblage of fossils is Ordovician.

The type of the genus *Huronia* is *Huronia bigsbyi* Stokes. In this species the segments of the siphuncle resemble short inverted pestles, the lower two-thirds of each segment being nearly cylindrical, the upper third enlarging more or less abruptly. *Huronia vertebralis* Stokes and *Huronia minuens* Barrande have the same types of structure. In *Huronia obliqua* Stokes, *Huronia turbinata* Stokes, and *Huronia distincta* Barrande the lower part of the segments of the siphuncle is turbinate rather than cylindrical. The figure of *Huronia portlocki* Stokes resembles that of an *Actinoceras* in which the septa are adnate to the lower face of the annular segments of the siphuncle. *Orthoceras persiphonatum* Billings also appears to be an *Actino-*

*ceras*. An examination of the types will be necessary to determine the relationship of these so-called *Huroniae*.

In typical *Huronia*, the septa are adnate to the lower part of the successive segments of the siphuncle, from the base of the cylindrical part of each segment up to the outer margin of the lower face of the annular enlargement at its top. *Huronia*, therefore, differs from *Actinoceras* only in the cylindrical elongation of that part of each segment of the siphuncle which lies beneath the annulation.

### 19. *Actinoceras* Sp.

*Plate XXVII, fig. 7; Plate XXXII, fig. 2*

*Actinoceras* sp. Høltedahl. On Some Ordovician Fossils from Boothia Felix and King William Land collected during the Expedition of the Gjoa. Videnskapsselskapets Skrifter, I, Mat-naturv. Klasse, 1912, No. 9, pl. III, fig. 2.

Figured specimen.—The specimen consists of the ventral side of a phragmacone. Owing to weathering, the siphuncle and the adjacent parts of the septa are exposed. Near the base of the specimen the segments of the siphuncle have a maximum diameter of 20 mm.; the same diameter is shown 100 mm. farther up, at the top of the specimen. The diameter of the conch at the upper end of the specimen is estimated at 60 to 65 mm. If this be correct then the diameter of the siphuncle is about one-third of that of the conch. The apical angle of the specimen is supposed to have been relatively small, possibly 5 degrees, but the evidence for such an apical angle is not satisfactory. The location of the siphuncle is strongly excentric. This is indicated by the slope of its segments, the latter forming an angle of about 60 degrees with the vertical axis of the siphuncle. In fact, the siphuncle probably was almost in contact with the ventral wall of the conch.

About 9 camerae occupy a length equal to the estimated diameter of the conch. Nothing is known about the exact direction of the sutures of the septa, but in other species with marginal siphuncles these sutures usually curve more or less strongly

downward on the ventral side of the conch. Where the diameter of the conch is 60 mm. the depth of concavity of the septa equals at least 16 mm. The segments of the siphuncle are strongly nummuloidal, contracting from a maximum diameter of 19 mm. to one of 14 mm at the lower margin of the septal necks. The latter are short, less than 1 mm. in length, the distance between successive segments of the siphuncle equalling scarcely 1 mm.

The central part of the siphuncle is occupied by a thick strand of calcareous deposits enlarging toward the top; from this central strand deposits radiate toward the upper part of the segments of the siphuncle. The strand itself consists of radiating elements 2 or 3 mm. wide, transversely concave when viewed from beneath, sometimes weathering so as to present an appearance slightly like that of a *Cystiphyllum*.

Locality and Horizon.—From some unknown locality, probably of Black River age, either on Boothia Felix or on King William Land. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Lieut. Godfred Hansen in 1903-04.

Remarks.—In the structure of its siphuncle this species resembles *Actinoceras tenuifilum* from the Black River limestone at Watertown, New York. It differs in having relatively more numerous camerae and the size of the siphuncle appears to be relatively much smaller. It probably is a new species but not sufficiently well preserved to serve as a type.

## 20. *Actinoceras* Sp.

### *Plate XXIX, fig. 2*

The specimen consists of a vertical dorso-ventral section of the phragmacone formed during the breakage of the rock. This section exposes the walls of the conch, the septa, and the hollow spaces formerly occupied by the nummuloidal segments of the siphuncle.

The apical angle of the specimen in a dorso-ventral direction is 9 degrees. The number of camerae in a length equal to the dorso-ventral diameter of the conch varies from 3 at the base

of the specimen, where the diameter of the conch is 23 mm., to 4 at its top where the diameter of the latter is 33 mm. The diameter of the siphuncle at these points is 15 and 21 mm. respectively. The siphuncle either is in actual contact with the ventral wall of the conch or is scarcely more than 1 mm. distant from the latter. The inner part of the groove separating successive nummuloidal segments of the siphuncle is so narrow and angular that the septal necks must have been short, possibly less than 1 mm. The septa are in contact with the lower side of the segments of the siphuncle. The nummuloidal segments incline at an angle of about 75 degrees with the vertical axis of the conch.

Locality and Horizon.—From some unknown locality, probably of Black River age, either on Boothia Felix or on King William Land. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Lieut. Godfred Hansen in 1903-04.

Remarks.—This species is characterized by its relatively large siphuncle and the relatively small number of camerae. In both of these respects, especially in the height of the camerae, it differs from *Actinoceras bigsbyi* Bronn, and it probably is a new species.

The specimen figured by Høltedahl from the Boothia Felix—King William Land area as *Actinoceras beloitense* Whitfield (Høltedahl, pl. IV, fig. 2) differs from all other forms here figured in its small siphuncle traversing relatively tall camerae. The number of annulations of the siphuncle in a length equal to its diameter is only two apparently.

#### 21. *Actinoceras tenuifilum centrale* Var. nov.

*Plate XXVIII, fig. 1; Plate XXXII, fig. 4*

Apical angle about 10 degrees; cross-section circular. Seven and a half camerae occupy a length equal to the diameter of the conch at the top of the series being counted. The sutures are almost directly transverse. The siphuncle is practically central in position, its distance from the ventral wall being 2 mm. less than its distance from the dorsal wall of the conch. Its diameter

equals 57 per cent of that of the conch. The curvature of the septa if continued to the center would cause a maximum concavity of 5 mm. where the diameter of the conch is 46 mm., and the segments of the siphuncle at this point contract from a maximum width of 26 mm. at the annulations to scarcely 19 mm. at the inner margin of the septal necks. The septa are adnate to the lower surface of the siphuncular annulations, becoming free from the latter along a circle 23 mm. in diameter. The septal necks curve downward for a distance of slightly more than one millimeter below the general curvature of the septae. The connecting rings that extend from the base of one septal neck to the septum next beneath form the annulations of the siphuncle, and in vertical sections they present strongly convex outlines laterally, while their upper surface curves strongly inward or even slightly downward on approaching the base of the septal necks. The vertical distance between consecutive siphuncular annulations is from one-fifth to one-fourth of the height of the camerae.

The surface of the conch is smooth or obscurely striated transversely with a tendency toward a slight groove at the sutures of the septa.

Locality and Horizon.—From Watertown, New York; occurring in the Black River limestone. Specimen from duplicate material in the New York State Museum of Natural History, at Albany, New York; presented by Dr. Rudolf Ruedemann.

Remarks.—*Actinoceras tenuifilum centrale* is distinguished from typical representatives of the species by the central position of its siphuncle; the camerae are relatively more numerous, producing a different outline in the segments of the siphuncle; at the same width of the conch, these segments do not diminish in size conspicuously toward the upper part of the conch. Additional specimens may prove this form to belong to a distinct species.

22. *Actinoceras* cf. *tenuifilum centrale*

*Plate XXVIII, fig. 4; Plate XXXII, fig. 5*

Specimens cut vertically through the center of the siphuncle, and polished to show the structure of the interior of the conch. The opposite part of the specimen ends abruptly within the matrix along a vertical plane passing along the most distant margin of the siphuncle in a direction parallel to the polished section, as though part of the specimen had weathered away before fossilization. The apical angle of the conch is estimated at 7 degrees. At the base of the specimen the width of the conch is 48 mm.; 8 camerae occupy a length equal to the diameter of the conch at the top of the series being counted. The septa are moderately concave, the amount of concavity equalling 10 mm. in a width of 48 mm. at the base of the specimen. At this point the maximum diameter of the segments of the siphuncle equals 23 mm., diminishing to 17.5 mm. at the lower margin of the septal necks. The siphuncle is moderately excentric in position; as far as may be determined from the specimen at hand, its distance from the ventral wall at the base of the specimen is about 9 mm., compared with a distance of 15 mm. from the dorsal wall. The septal necks descend about 1 mm. below the general curvature of the septa, the intervals between successive segments of the siphuncle equalling about 1.5 mm.

Locality and Horizon.—From some unknown locality, probably of Black River age, either on Boothia Felix or on King William Land. Collected in 1903–04 by Lieut. Godfred Hansen. In the Palaeontologisk Museum, Kristiania, Norway.

Remarks.—Compared with either *Actinoceras tenuifilum centrale* or the variety *ursinum* the siphuncle of the specimen here described is relatively smaller. It is impossible to determine whether the siphuncle actually becomes narrower toward the top, as in *Paractinoceras*, or whether the appearance of narrowing in this direction is due to the section having been cut more or less oblique to the vertical axis. In the relative number of camerae this specimen approaches the variety *ursinum*. It probably is a distinct variety, but the specimen is inadequate for more exact discrimination.

23. *Actinoceras tenuifilum ursinum* Var. nov.

*Plate XXVIII, fig. 3; Plate XXXII, fig. 6*

*Actinoceras Bigsbyi* (-*A. tenuifilum* ?) Høltedahl, Paleozoic Series of Bear Island, 1919, p. 131, pl. 13, fig. 5.

Apical angle 16 degrees. Siphuncle apparently nearly central, its diameter varying from 65 per cent of that of the conch at the base of the specimen to 57 per cent at its top. From 9 to 9.5 camerae occupy a length equal to the diameter of the conch at the top of the series being counted. The structure of the annular segments of the siphuncle and the degree of concavity of the septa closely resembles that of *Actinoceras tenuifilum centrale*, from the Black River limestone of Watertown, New York. The chief differences consist in the relatively greater number of camerae and in the greater apical angle of the conch.

Locality and Horizon.—From the western part of the Antarctic Mountain area on Bear Island. In the *Tetradium* limestone member of the Hecla Hook System, regarded as of Black River age. Original of figure 5 on plate 13 in the publication cited above. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Høltedahl in August, 1918.

Remarks.—The species later named *Actinoceras Bigsbyi* by Bronn was first figured and described by Bigsby from the equivalent of the Black River limestone on Thessalon Island in the northwestern corner of Lake Huron. Bronn's first figure (Leth. Geog., 1, 1837, p. 98, Plate I, fig. 8) is a reproduction of Bigsby's figure 1 on plate 25 of the Trans. Geol. Soc. London, 1, 1824, p. 198, in which, according to Foord, the segments of the siphuncle are not oblique to the long axis of the siphuncle (Foord, Catalogue of Fossil Cephalopoda, 1888, p. 170). Bronn's second figure, published on his plate 1', is that of a species having oblique segments of the siphuncle, the latter being in contact with the ventral wall of the conch. Since Bronn's first figure must be regarded as the type, it would be desirable to know how closely it resembles the form here described as *Actinoceras tenuifilum centrale*. As far as can be judged from the figure presented by Bigsby, *Actinoceras bigsbyi* has an apical angle of

only 8 degrees, about 6.5 camerae occupy a length equal to the diameter of the conch, and the diameter of the siphuncle is about half of that of the conch.

Under these conditions, *Actinoceras tenuifilum* is not considered as identical with *Actinoceras bigsbyi* nor with the Bear Island species here under consideration. How close the relationship of the Bear Island species is to *Actinoceras bigsbyi* can not be determined until a more exact knowledge of the type of the latter has been obtained. Judging from the greater apical angle of the Bear Island form, its more numerous camerae, and its relatively wider siphuncle, there is a probability of its proving distinct from typical *Actinoceras bigsbyi*. Its resemblance to *Actinoceras tenuifilum centrale* is greater, but even in this case differences may be noted and additional material will be required to determine the degree of relationship.

#### 24. *Actinoceras parksi* Sp. nov.

##### *Plate XXXV, fig. 3*

*Actinoceras bigsbyi* Parks, Trans. Royal Canadian Inst., 11, 1915, p. 23, pl. 6, fig. 7.

Type.—Specimen a fragment 140 mm. in length, consisting of one side of the phragmacone, exposing both the outer wall of the conch and the wall of the siphuncle. The conch enlarges at a rate of 18 mm. in a length of 100 mm. in a lateral direction, indicating an apical angle of  $10^{\circ}$  in that direction. The conch apparently is depressed in a dorso-ventral direction, but the depression appears to consist chiefly in a flattening of the median part of the ventral side. If this flattening is not due in part to compression during fossilization, then it must have formed a conspicuous feature of the original complete specimen. Possibly the dimensions at the larger end of the specimen were 68 mm. in a lateral direction and 52 mm. in a dorso-ventral one. At the smaller end of the specimen the corresponding dimensions appear to have been 48 and 44 mm. The rapid increase in the amount of flattening of the ventral side toward the upper end of this specimen appears to be too great to be normal, thus

suggesting that at least part of the flattening may be due to compression during fossilization.

The sutures of the septa apparently incline from the dorsal toward the ventral side of the conch at an angle of about  $75^{\circ}$  with the dorsal side of the conch, which suggests an angle of about  $85^{\circ}$  with the ventral side; however, the rate of inclination is only an estimate. The location of the siphuncle is 22 mm. from the dorsal wall at the top of the specimen, where the lateral diameter is 68 mm.; on the ventral side the siphuncle probably was in contact with the ventral wall of the conch, and even may have suffered a certain amount of flattening there. At the top of the specimen the lateral diameter of the siphuncle is estimated at 43 mm.; at its base it probably was 33 or 34 mm., indicating an increase in width of 10 or 11 mm. in a length of 125 mm.; or an apical angle of about 5 degrees. In a length equal to the lateral diameter of the conch there are 6 camerae; in a length equal to the lateral diameter of the siphuncle there are about 4 camerae or at least nearly that number.

At the top of the specimen, where the vertical distance between the septa along the siphuncle is 10 mm., the short tubular necks of the septa extend downward 4.5 mm., the connecting rings joining successive septal necks having a vertical lengths of 5.5 mm. These connecting rings or annulations extend abruptly outward beyond the tubular septal necks for distances of 4.5 mm. The septa practically are in contact with the lower surface of the annular segments of the siphuncle for a distance of 4 mm. from the upper margin of the septal necks. Along this part of their course they form an angle of about  $60^{\circ}$  with the dorsal side of the siphuncle, rising 17 mm. in passing from the upper margin of the septal necks to the dorsal wall of the conch.

Calcareous deposits fill the interior of the annulations along the lower part of the specimen, but along the upper part of the latter the distal part of the annulations is occupied only by the same sort of matrix which has filtered also into the camerae, indicating that it was unoccupied at the time of the death of the animal. From the interiors of these annulations the calcareous deposits extend nearly horizontally inward for 3 or 4 mm. toward the interior of the siphuncle.

The surface of the conch apparently was smooth.

Locality and Horizon.—From the Lower Rapids on the Shattawawa River, in northern Manitoba. In the Ordovician.

No. 308S, in the Royal Ontario Museum of Paleontology at Toronto.

Remarks.—This species is characterized by the relatively long tubular septal necks separating the relatively narrow, abruptly projecting annulations.

### 25. *Cyclendoceras annulatum* (Hall)

*Plate XXXI, fig. 3*

*Endoceras annulatum* Hall, Pal. New York, 1, 1847, p. 207, pl. 44, figs. 1a, 1b. *Cyclendoceras annulatum* Grabau and Shimer, N. Am. Index Fossils, 2, 1910, p. 43, fig. 1241.

Type specimen.—Phragmacone 225 mm. in length, retaining 26 camerae in a length of 22 mm.; of these the lower 5 occupy at length of 38 mm. and the upper 5 a length of 42 mm. Since only 16 transverse annulations occur in this length of 26 camerae it is evident that the rhythmic enlargement of the aperture of the shell at the annulations has no connection with the periodic withdrawal of the lower part of the animal from contact with the basal part of the living chamber. The specimen enlarges from a diameter of 59 mm. at its base to 70 mm. at a point 185 mm. farther up, or at the rate of 6 mm. in a length of 100 mm., thus indicating an apical angle of 3.5 degrees. About 7 camerae occur in a length equal to the diameter of the conch. The cross-section of the conch is nearly circular.

The sutures of the septa are directly transverse or only slightly lower on the ventral side. The concavity of the septa is about one-fifth of the diameter of the conch. On the ventral side of the conch the vertical sections of the septa have straight courses from the wall of the conch to within 3 mm. of the siphuncle. On the dorsal side the concave curvature of the septa, from the wall of the conch, to within 3 mm. of the siphuncle, only slightly exceeds 1 mm. Beginning 3 mm. from the siphuncle, the inner parts of the septa curve strongly downward, coming in contact with

the lower part of the funnel of the septum beneath at a point about 4 or 5 mm. below the general concave curvature of this lower septum. The septal funnels contract slightly about 2 mm. before reaching contact with the funnels next beneath, and continue downward to a point slightly more than half the length of the second camera beneath the septum at which the funnel originates. The diameter of the siphuncle is one-third of that of the conch, and its ventral side is distant one-fifth of the diameter of the conch from the ventral wall.

The annulations of the conch are low and broad, rising only 1 mm. above the intermediate grooves. They cross the conch obliquely, descending from the dorsal toward the ventral side a distance slightly exceeding the height of one camera, at an angle of about 12 degrees with a horizontal line. The interior of the siphuncle of the type exposes only a single endocone having a length between 100 and 110 mm.

Locality and Horizon.—From the Trenton limestone at Middleville, New York. Type, numbered 811, in the American Museum of Natural History in New York city.

Remarks.—*Cyclendoceras annulatum* probably is confined to the typical Trenton of New York and of the immediately adjacent states. Similar species occur in approximately similar horizons in adjoining geological provinces. The species described and figured by Whiteaves (Trans. Royal Soc. Canada, 9, 1891, p. 77, pl. 5, figs. 1, 1a) from the Trenton (Black River?) between the second and third rapids of the Nelson River, west of Hudson Bay, enlarges much less rapidly and has much more oblique annulations. It is a distinct species.

In typical *Cyclendoceras* the annulations usually are distinctly more prominent on the ventral than on the dorsal side of the conch. The sutures of the septa curve slightly downward both on the ventral and on the dorsal side. The most striking feature usually is the strong downward curvature of the annulations along the ventro-lateral sides of the conch, and their relatively broad concave curvature across the ventral side. Across the dorsal side of the conch their course may be nearly straight or slightly curved either in an upward or in a downward direction.

Annulated *Endoceratidae*, such as here are included in *Cyclendoceras*, are very well known in northern faunas. At least a dozen species have been studied. They occur in loose Black River blocks west of Cape Chidley at the northern end of Labrador, on the Nelson and Shamattawa rivers west of Hudson Bay, in Manitoba, and along that Arctic invasion which extended southwestward to the Black Hills of South Dakota, the Big Horn Mountains of Wyoming, the Teton range of Idaho, and the Canyon City area of Colorado. At least 6 species are known from this southwestern extension of the Arctic invasion. Two species occur in Wisconsin, and 2 occur in the Watertown area of New York, one of which, *Cyclendoceras annulatum*, a Trenton form, is the genotype.

## 26. *Cyclendoceras* or *Dawsonoceras* sp.

### *Plate XXXI, fig. 2*

*Endoceras* (*Cyclendoceras*) *annulatum* Hall, On Some Ordovician Fossils from Boothia Felix and King William Land, collected during the Expedition of the Gjoa. Videnskapssilkeapets Skriften, 1912. Pl. IV, fig. 1.

*A. Specimen figured by Høltedahl.*—Diameter at lowest well preserved annulation, 57 mm. Rate of enlargement of conch, 3 degrees or less. Compressed, partly subsequent to death, the shorter diameter equalling about 77 per cent of the longer one. Five camerae occur in a length equal to the longer diameter of the conch, each camera being occupied by a transverse annulation whose crest is located slightly above mid-height of the camera. The sutures rise gently toward a point which is slightly toward the left of the median line of the published figure. Toward the right of this point, both sutures and annulations are almost directly transverse. Toward the left, both sutures and annulations curve downward, but much more moderately than in typical *Cyclendoceras*.

*B. Specimen figured in this Bulletin (Plate XXXI, fig. 2).*—Seven annulations occur in a length equal to the diameter of the conch. These annulations rise 1.5 mm. above the intervening grooves.

Their crests are broadly rounded and are approximately of the same width as the intervening grooves. The annulations rise toward a point which is slightly toward the left of the median line of the figure here published.

In the moderate curvature of the annulations, both specimens resemble *Dawsonoceras* rather than *Cyclendoceras*. In addition to the two specimens described above, a third one was sent by Dr. Høltedahl. Two of them apparently present faint traces of vertical ribs, but not sufficiently distinct to give confidence to their determination as *Dawsonoceras*. In the absence of any knowledge of their siphuncles, their apparent association with Ordovician forms favors their reference to *Cyclendoceras*.

Locality and Horizon.—From some unknown locality on Boothia Felix or King William Land. Collected in 1903–04 by the Gjoa expedition. Deposited in the Palaeontologisk Museum, at Kristiania. From the Silurian, in strata equivalent to the Niagaran or Guelph.

## 27. *Eurystomites* (?) *boreale* Foord

*Plate XXXIII, figs. 9 A, C*

*Trochoceras boreale* Foord, Catalogue of Fossil Cephalopoda in the British Museum of Natural History, pt. II, 1891, p. 23.

Original description.—“*Sp. Char.* Shell discoid, compressed, whorls in contact, about three in number, all exposed. Section elliptical, the ratio of the two diameters about as 6: 8; siphuncle between the centre and the convex side. Septa approximate; two lines apart on the sides, where the shell has a diameter of 11 lines, increasing to  $2\frac{1}{2}$  lines where the diameter is  $1\frac{1}{2}$  inches. Body-chamber and test unknown. There are no indications of ribbing or of any ornaments upon the cast.

“*Remarks.* This is a much larger species than any of those of the Niagara rocks of North America that come at all near to it. *Trochoceras Aeneas*, Hall, agrees with it in the distance of the septa and position of the siphuncle, but the section is different, and there are marks of very distinct annulations upon the cast. Salter (Journal of a Voyage in Baffin’s Bay and Barrow Straits in the years 1850–1851, by Dr. P. C. Sutherland (1852), Appendix, p. ccxxii) described, amongst

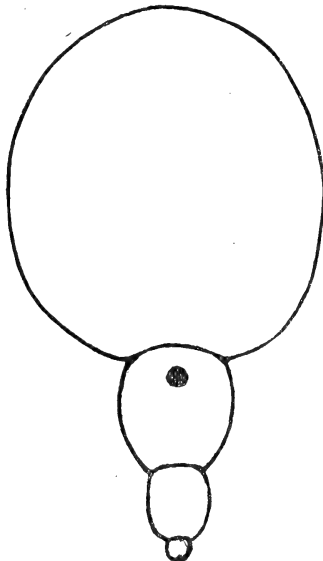
other Arctic Silurian fossils, one which he called "Lituites—, n. sp.;" but this is stated to have six or seven whorls at least, and therefore it could have no affinity with the present species. There was, therefore, no other course but to give this form a new name.

"*Horizon.* Silurian.

"*Locality.* Wellington Channel, Arctic America.

"Represented in the Collection by one example, collected by Captain Inglefield."

The specimen described above is numbered 96955 in the British Museum. Dr. F. A. Bather has kindly presented me with an excellent cast of the type, also a photograph, and a cross-section. Both the cast and the photograph suggest that the color of the matrix is black. The cross-section is accompanied by the following annotations, evidently applicable to that whorl which exposes the siphuncle: Siphuncle circular, diameter 2.2 mm.; distance from venter, 2.8 mm.; dorso-ventral diameter of whorl, 15.7 mm.; lateral diameter 13.8 mm.



EURYSTOMITES (?) BOREALE (FOORD). CROSS-SECTION OF TYPE, SHOWING LOCATION OF SIPHUNCLE. DRAWN BY DR. F. A. BATHER

From this cross-section it is evident that the conch is a nautilus with a distinctly impressed dorsal side. Since no reference

is made to enlargement of the segments of the siphuncle within the camerae, these segments may be regarded as cylindrical in form. From the cast it appeared possible to secure a transverse section of the whorl (at the point B in fig. 9A on Plate XXXIII of this paper) which is angularly elliptical (as in fig. 9B of the plate just cited), but the excellent cross-section presented by Dr. Bather removes all doubt about the outline of the whorls. Laterally, the sutures of the septa are gently concave when viewed from above, but nothing is known of their direction along the ventral side of the conch.

I do not know of any Silurian nautiloid combining the characteristics here noted. Among Ordovician forms the cast of the interior of the some species of *Plectoceras* present a somewhat similar appearance on lateral view. However, the Wellington channel specimen is not known to have its sutures curving distinctly downward, along the *ventral* side of the conch, as in typical *Plectoceras*. The absence of any indication of obliquely transverse plications on the ventro-lateral sides of the specimen is not sufficient to exclude it from *Plectoceras*, since casts of the interior of some species of this genus do not show readily recognizable undulations, even when these are quite boldly marked on the exterior. The shell of typical *Plectoceras* is so thick that the interior may be quite smooth even in the presence of a strongly ribbed exterior.

I do not know of any Silurian species of *Plectoceras*. *Plectoceras jason* and *Plectoceras tyrans* were described by Billings from the Chazyan of the Mingan Islands, in northeastern Canada. *Plectoceras bondi* was described by Safford from the Stones River of central Tennessee. *Plectoceras undatum* described by Conrad from the Black River at Watertown, New York. *Plectoceras occidentale* was described by Hall from the Platteville of Wisconsin. *Plectoceras halli* was described by Foord from the Black River near Quebec, in Canada. The Wellington Channel species described by Foord under *Trochoceras boreale* may not belong to *Plectoceras*. Its affinities may be with *Eurystomites*, in which the shell is not conspicuously costated. This would place it among the *Tarphyceratidae*.

28. *Orthoceras* Sp.

*Plate XXXIV, fig. 3 A, B*

On the Fossil Faunas from Per Schei's Series B in South-western Ellesmereland, Rep. Second Norwegian Arctic Expedition, in the "Fram" 1898-1902, No. 32, 1914, p. 32.

Fragment 15 mm. long, consisting of a single camera 3.5 mm. in length, surmounted by the lower part of a living chamber 17 mm. in length. No trace of the aperture is present, so that the original length of the living chamber can not be determined. Moreover, the single camera present is so long that the conch probably is immature, so that the size of a mature specimen also remains unknown. The suture of the septum inclines at an angle of about 75 degrees with the vertical axis of the conch from the dorsal toward the ventral side of the conch. This suture is almost straight, with a slight tendency toward horizontality along the middle of the lateral sides. The cross-section of the conch is transversely elliptical. The lateral diameter being 14 mm., and the dorso-ventral one slightly over 11 mm. The ventral side is distinctly more flattened than the dorsal one. The septum is quite evenly concave, the depth of the concavity being 2.5 mm. At its passage through the septum the siphuncle is 2.3 mm. in diameter; its center is 6 mm. from the dorsal margin of the septum and an equal distance from the ventral margin, but, measured in a direction strictly transverse to the vertical axis of the conch, it is 5 mm. from the dorsal side of the latter and 6 mm. from its ventral side, thus being slightly dorsad of the center of the conch. A vertical section through the center of the camera failed to reveal any trace of the siphuncle except at its passage through the septa. The septal neck apparently was confined to a slight downward inflection of the septum. The surface of the shell appears to be smooth.

Locality and Horizon.—Valley south of Borgen in Goose Fjord, in southwest corner of Ellesmereland. From the fragmental limestone in the upper part of series B of Per Schei. Collected by Per Schei June 28, 1902, and deposited in the Paleontological Collections of Kristiania University.

Remarks.—Attached to the upper part of the specimen are a brachial valve of *Camarotoechia litchfieldensis angustata* Hortedahl and a pedicel valve of *Spirifer vanuxemi prognostica* Schuchert, the only two brachiopods known so far from this fragmental limestone horizon. Unknown species of *Fistulipora* and *Fenestella* complete our present knowledge of the fauna from this horizon, which is correlated by Hortedahl with the Keyser member of the Helderbergian.

#### PLATE XXVII

Fig. 1. Cf. *Euconia quebecensis* Billings. The more apical part of the specimen consists of a vertical section passing through the center of the umbilicus. At the base, parts of the two lower whorls are exposed along oblique surfaces. From Victoria Head on Bache Peninsula, Ellesmereland; in the *Orthoceras* limestone, regarded as of Canadian age. In the Palaeontologisk Museum, Kristiania; collected by Per Schei in 1899. Size 22/10.

Fig. 2. *Clarkoceras hortedahli* Sp. nov. A, an obliquely lateral view; a rectangular section has been cut out from the right half of the ventral side of the conch; one side of this section is parallel to the dorso-ventral diameter, the other side is at right angles to the first; the former exposes the siphuncle, and the second shows the strong lateral concave curvature of the septa. B, a strictly lateral view of the same specimen, with an attempt to indicate the probable dorsal and ventral outlines of the conch. Figure 1 on Plate 33 is a cross-section of this specimen, made at the seventh septum above its base. From Victoria Head on Bache Peninsula, Ellesmereland; in the *Orthoceras* limestone, regarded as of Canadian age. In the Palaeontologisk Museum, Kristiania; collected by Per Schei in 1899.

Fig. 3. *Ellesmeroceras scheii* Gen. et Sp. Nov. A, ventral view, showing rise of sutures toward the siphuncle; size 22/10. B, the same view, but of natural size. C, lateral view, with siphuncle on extreme right of figure; along the left side of figure the sutures are not preserved. Figure 3 on Plate 33 is a cross-section of the conch taken at the top of the phragmacone, the position and size of the siphuncle being inferred from the actual exposure of this siphuncle at the base of the specimen. From Victoria Head, on Bache Peninsula, Ellesmereland; in the *Orthoceras* limestone, regarded as of Canadian age. In the Palaeontologisk Museum, Kristiania; collected by Per Schei in 1899.

Fig. 4. Cf. *Cameroceras tenuiseptum* (Hall). A, lateral view, with septa not preserved on left side; sutures of septa apparently form shallow lobes. B, another view, oriented so as to show the right side of figure 4A; the irregularities in the course of the septa are due to irregular weathering of the surface of the specimen. C, basal view of same specimen, showing cross-section of specimen in its present condition, no definite knowledge regarding the siphuncle is presented. Generic reference uncertain. From Victoria Head, on Bache Peninsula, Ellesmereland; in the *Orthoceras* limestone, regarded as of Canadian age. In the Palaeontologisk Museum; Kristiania; collected by Per Schei in 1899.

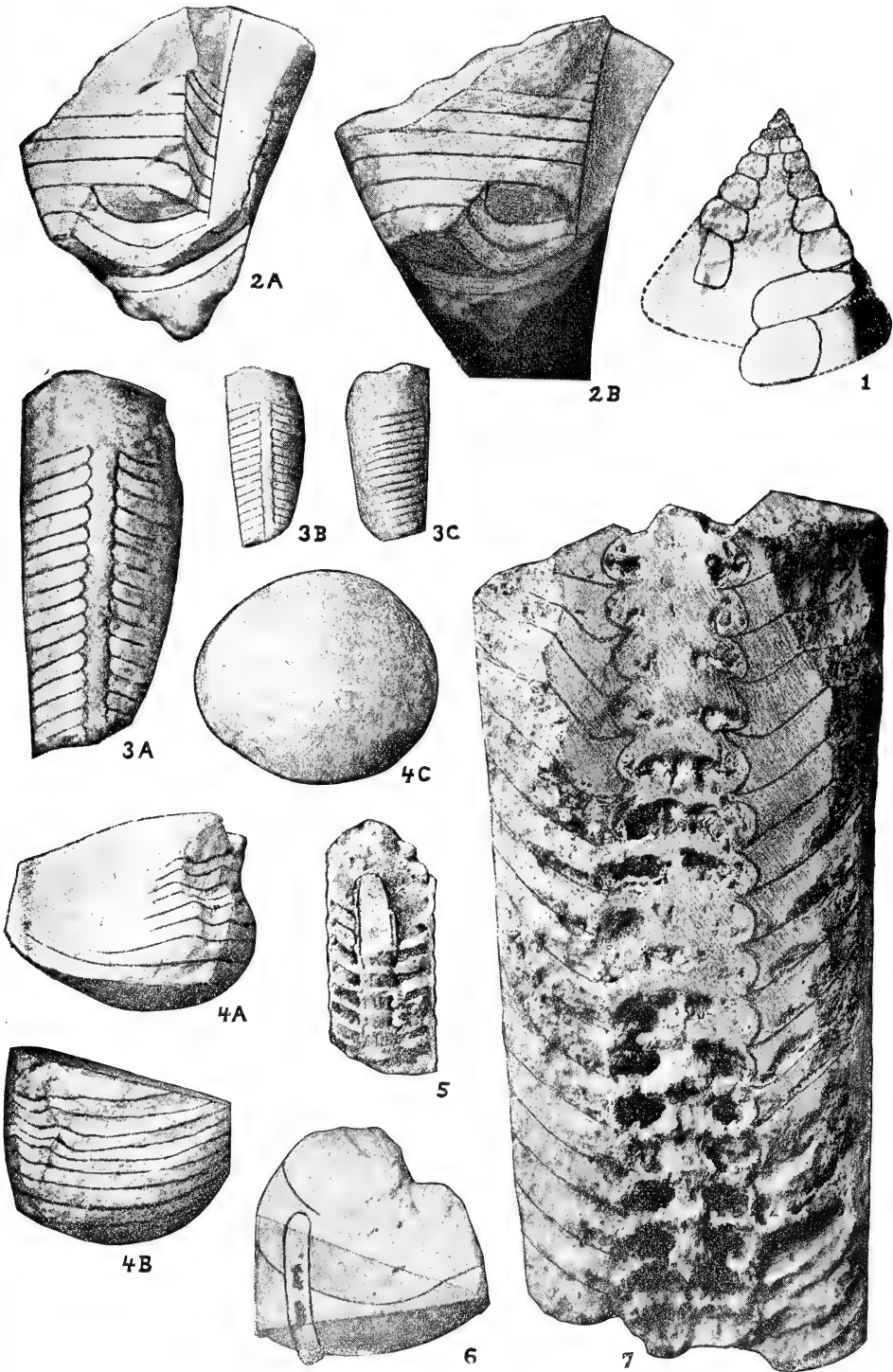


Fig. 5. *Protocycloceras* cf. *lamarcki* (Billings). A natural vertical section exposing the siphuncle, apparently with invaginating septal necks. Figures 5A and 5B on Plate 33 represent a cross-section and a vertical section of this specimen, as far as can be determined from the part preserved. From Bear Island; in the younger dolomite division of the Heclahook system, regarded as of Canadian age. In the Palaeontologisk Museum, Kristiania; collected by Dr. Olaf Holtedahl in July, 1918. Original of fig. 1 on Plate XIII on Holtedahl's paper "On the Paleozoic Series of Bear Island," 1919.

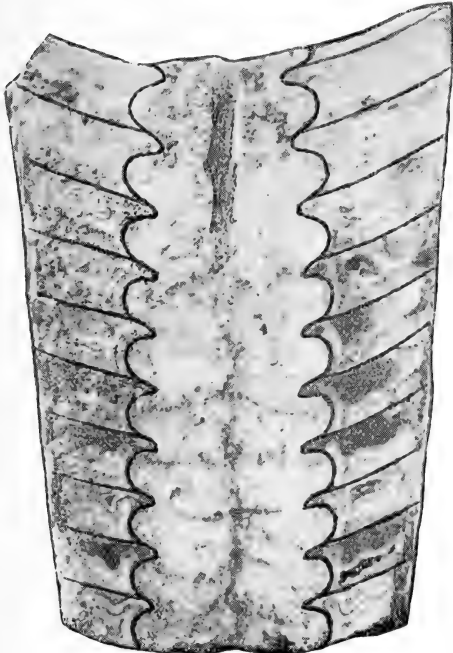
Fig. 6. *Deltoceras* (?) sp. A section lengthwise through the siphuncle and parallel to the dorso-ventral diameter, exposing the outline of the septa; triangularly limited by two oblique sections, of which the lower one is margined by a second septum, while the upper oblique section exposes only the ventral part of a third septum. Figures 6A and 6B Plate 33 represent the same specimen, the first in its present condition, the second with an attempt at restoration, the missing parts being indicated by dotted lines. Figure 6C' on the same plate is a cross-section of the specimen. From Bear Island; in the younger dolomite series of the Heclahook system, regarded as of Canadian age. In the Palaeontologisk Museum, Kristiania; collected by Dr. Olaf Holtedahl in July, 1918. Figure 2 on Plate XIII of Holtedahl's paper "On the Paleozoic Series of Bear Island," is a direct view of the septum at the base of the specimen, before this specimen was sectioned.

Fig. 7. *Actinoceras* sp. A vertical section passing in a lateral direction through the siphuncle; along the lower half of the specimen the exposure is due to weathering, along its upper half the weathered surface has been ground off sufficiently to expose the outlines of the annulations of the siphuncle. Along the center of the siphuncle is the heavy strand-like deposit characteristic of numerous species of *Actinoceras*. Figure 2 on Plate 32 is an attempt at a cross-section of this specimen, suggesting that its siphuncle was small compared with the diameter of the conch. From some unknown locality either on Boothia Felix or on King William Land; probably from the Black River limestone. In the Palaeontologisk Museum, Kristiania; collected by Lieut. Godfred Hansen in 1903-04. Original of Fig. 2 on Plate III of Holtedahl's paper "On Some Ordovician Fossils from Boothia Felix and King William Land," 1912, however, since the publication of Holtedahl's paper the matrix has been ground away from the left side of the specimen in an attempt to get some idea of the original size of the conch.

## PLATE XXVIII

Fig. 1. *Actinoceras tenuifilum centrale* Var. nov. A vertical section through the center of the siphuncle. The apparent narrowing of the siphuncle at the top of the specimen is due to oblique weathering. The axial part of the siphuncle is occupied by an irregular tube filled by dark matrix; this is exposed by weathering at the top of the specimen and is glimpsed through the calcareous deposit in the lower part of the specimen. There also are traces of the tubuli which radiate from this axial part toward the annular segments of the siphuncle. Figure 4, on Plate 32 is a cross-section of the same specimen. From the Black River limestone at Watertown, New York. Received from Dr. Rudolf Ruedemann of the New York State Museum of Natural History.

Fig. 2. *Actinoceras tenuifilum* (Hall). A vertical section through the center of the siphuncle, the latter narrowing toward the top. In the upper part of the specimen the axial part of the specimen was still comparatively open before



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2



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4

the infiltration of the dark matrix. Toward the base of the specimen this tubular part is very much contracted. Traces of the tubuli radiating from the axial part also are present. Figure 1 on Plate 32 is a cross-section of the same specimen. From the Black River limestone at Watertown, New York. Received from Dr. Rudolf Ruedemann of the New York State Museum of Natural History.

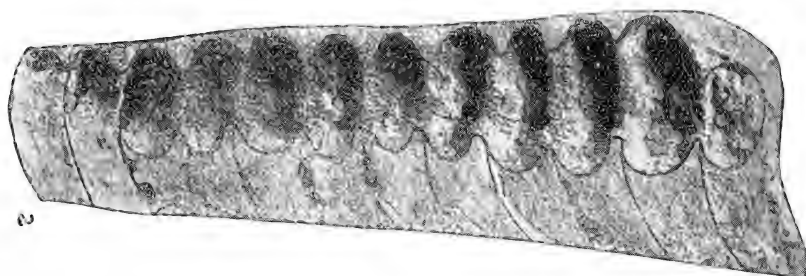
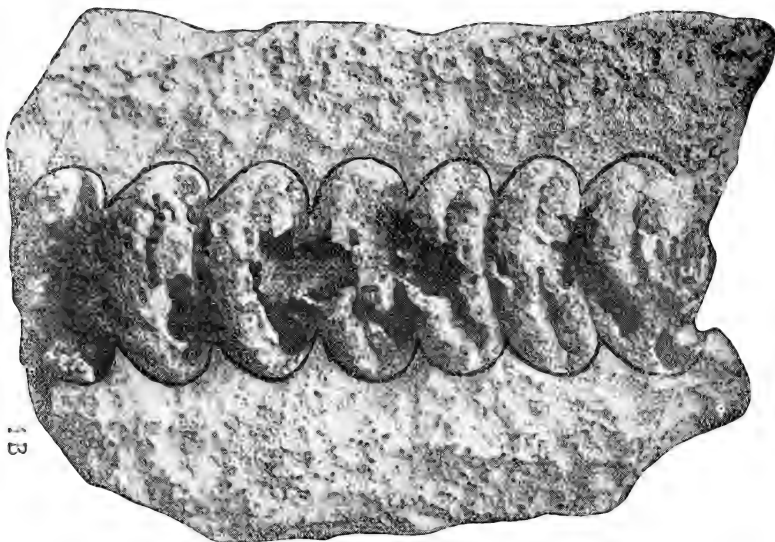
Fig. 3. *Actinoceras tenuifilum ursinum* Var. nov. A vertical section exposing the siphuncle but not passing through the axial part of the latter. The cross-sections of this axial part, at the top and bottom of the specimen, show that it is dark in color like the matrix but very irregular in outline. Traces of the tubuli which radiate from the central axis are seen most distinctly where they approach the annular segments of the siphuncle, but a few cross-sections of these tubuli are visible near the axial parts of the siphuncle. Figure 6 on Plate 32 is a cross-section of this specimen. The same specimen as Figure 5 on Plate XIII of Hortedahl's paper "On the Paleozoic Series of Bear Island," 1919. From the *Tetradium* limestone of the Heclahook system on Bear Island, regarded as of Black River age. In the Palaeontologisk Museum at Kristiania, Norway.

Fig. 4. *Actinoceras* cf. *tenuifilum centrale*. A vertical section passing through the siphuncle. The latter apparently narrows toward the top. Figure 5 on Plate 32 is a cross-section of this specimen. From dolomitic strata of Black River age on either Boothia Felix or King William Land. In the Palaeontologisk Museum, at Kristiania, Norway; collected by Lieut. Godfred Hansen in 1903-04.

#### PLATE XXIX

Fig. 1. *Actinoceras amundseni* Sp. nov. A, ventral side of phragmacone, showing angular hyponomic sinus. B, opposite side of the same specimen, showing the siphuncle; the outline of the segments of the siphuncle are presented best by the lower part of the specimen. Figure 3 on Plate XXXII is an attempt at a restoration of its cross-section. From dolomitic strata of Black River age either on Boothia Felix or King William Land. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Lieut. Godfred Hansen in 1903-04.

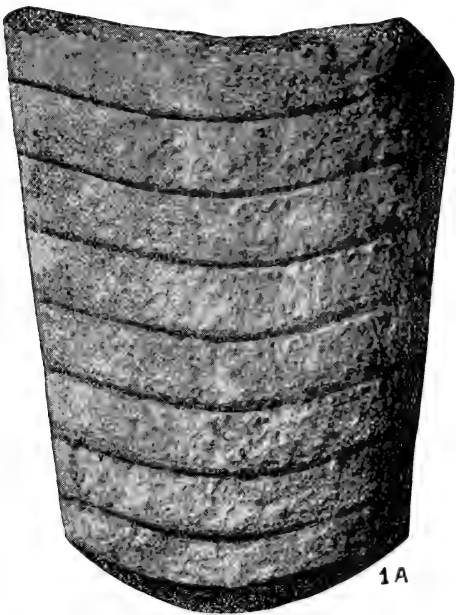
Fig. 2. *Actinoceras* sp. A natural vertical section of the phragmacone, showing the ventral location of the siphuncle and its relatively large size. From dolomitic strata of Black River age on either Boothia Felix or King William Land. In the Palaeontologisk Museum, Kristiania, Norway. Collected by Lieut. Godfred Hansen, in 1903-04.



### PLATE XXX

Fig. 1. *Leurorthoceras hanseni* Gen. et Sp. nov. *A*, ventral side; *B*, dorsal side; the lateral side is shown by Figure 1 on Plate 31, with the ventral side facing toward the right. Figure 8 on Plate 32 is a cross-section of this specimen, showing the flattening of the ventral side. Either from Boothia Felix or from King William Land; in dolomitic strata regarded as of Black River age. In the Palaeontologisk Museum, Kristiania; collected by Lieut. Godfred Hansen in 1903-04.

Fig. 2. *Actinoceras* sp. *A*, ventral side of phragmacone; *B*, an oblique lateral view, showing most of the ventral side, and exhibiting the transverse striae along the ventro-lateral angle of the conch. Figure 7 on Plate 32 presents the transverse outline of this specimen near its top, but the ventral outline of the siphuncle is not known definitely. Either from Boothia Felix or from King William Land; in dolomitic strata regarded as of Black River age. In the Palaeontologisk Museum, Kristiania; collected by Lieut. Godfred Hansen, in 1903-04.

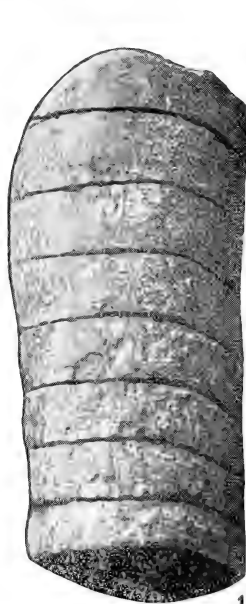


### PLATE XXXI

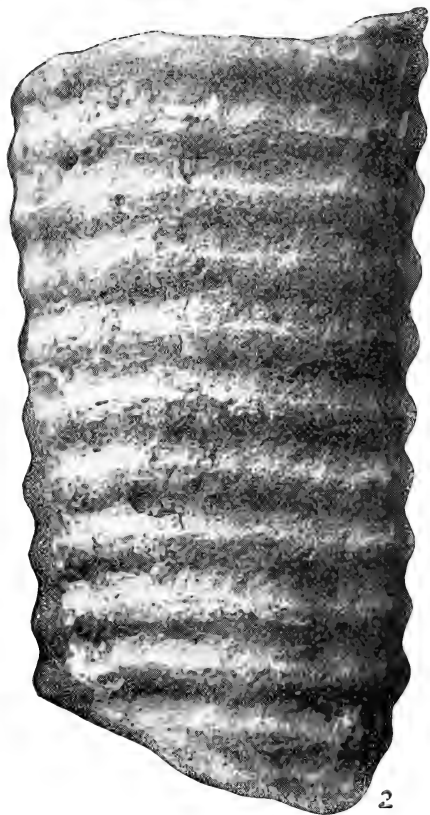
Fig. 1. *Leurorthoceras hansenii* Gen. et Sp. nov. Lateral view of specimen figured on Plate 30 (fig. 1), with the ventral side facing toward the right.

Fig. 2. *Cyclendoceras* or *Dawsonoceras*. Apparently a part of a living chamber, with the median line of the ventral side about 10 mm. from the right margin of the figure. Either from Boothia Felix or from King William Land; from dolomitic strata regarded as of Ordovician age, but which may turn out to be Niagaran. In Holtedahl's paper "On Some Ordovician Fossils from Boothia Felix and King William Land," Figure 1 on Plate IV presents another species collected during the same expedition and undoubtedly from the same locality; in this specimen the sutures of the septa occupy the grooves between the annulations.

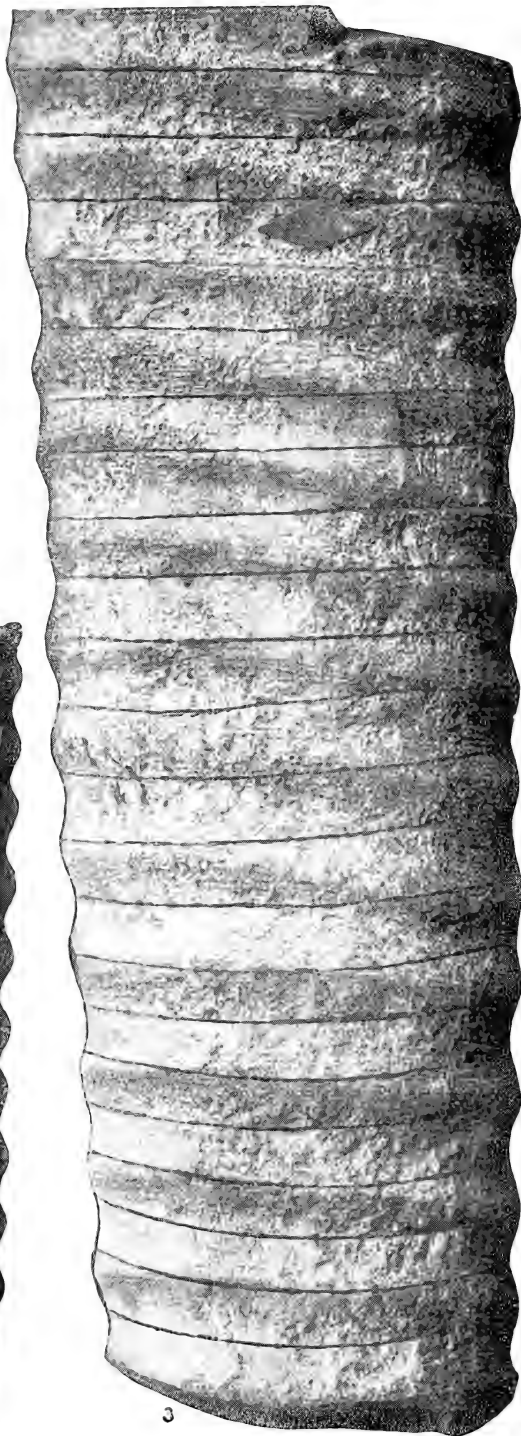
Fig. 3. *Cyclendoceras annulatum* (Hall). All but the extreme top of the type described and figured by Hall (Pal. New York, 1, 1847, pl. 44, figs. 1a, 1b). The ventral side is on the right of the figure. From Watertown, New York; in the Trenton limestone. No. 811 in the American Museum of Natural History in New York City.



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2



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## PLATE XXXII

Fig. 1. *Actinoceras tenuifilum* (Hall). Cross-section of specimen, Figure 2 on Plate 28, from Watertown, New York.

Fig. 2. *Actinoceras* sp. Cross-section of specimen, Figure 7 on Plate 27, from either Boothia Felix or King William Land.

Fig. 3. *Actinoceras amundseni* Sp. nov. Cross-section of specimen, Figure 1, on Plate 29, from either Boothia Felix or King William Land.

Fig. 4. *Actinoceras tenuifilum centrale* Var. nov. Cross-section of specimen, Figure 1 on Plate 28, from Watertown, New York.

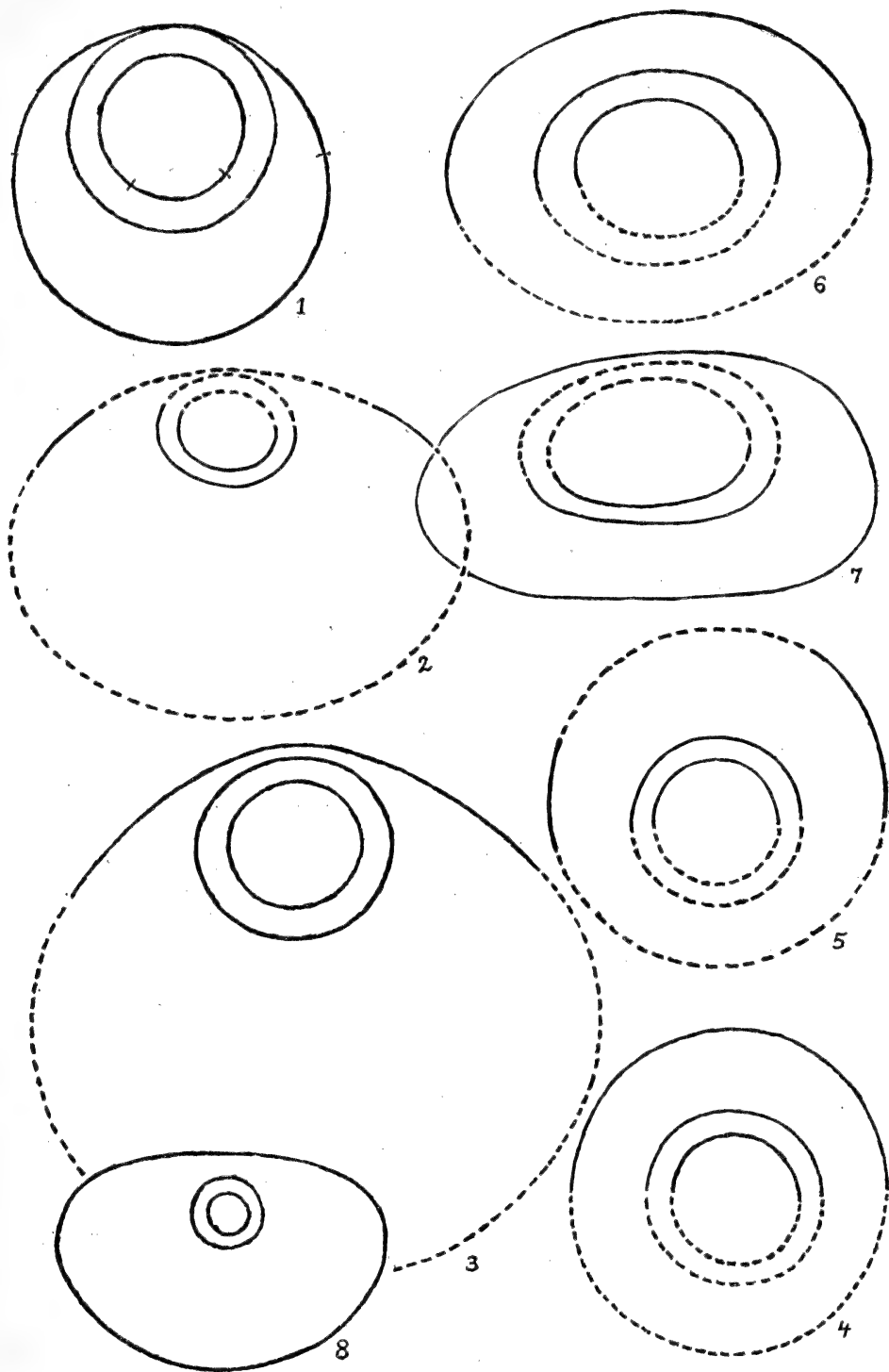
Fig. 5. *Actinoceras* cf. *tenuifilum centrale* var. Cross-section of specimen, Figure 4 on Plate 28, from either Boothia Felix or King William Land.

Fig. 6. *Actinoceras tenuifilum ursinum* Var. nov. Cross-section of specimen, Figure 3 on Plate 28, from Bear Island.

Fig. 7. *Actinoceras* sp. Cross-section of specimen, Figure 2 on Plate 30, from either Boothia Felix or from King William Land.

Fig. 8. *Leurorthoceras hansenii* Gen. et sp. nov. Cross-section of specimen, Figure 1 on Plate 30 and Figure 1 on Plate 31, from either Boothia Felix or from King William Land.

In all of these figures the missing parts are indicated by broken lines. Both the maximum and minimum dimensions of the siphuncle at the annulations and at the intermediate grooves are indicated.



### PLATE XXXIII

Fig. 1. *Clarkoceras holtedahli* Sp. nov. Cross-section of specimen, Figure 2 on Plate 27, from Bache peninsula.

Fig. 2. *Eremoceras syphax* (Billings). Cross-section of specimen, Figure 8 on this plate, from Point Levis, Quebec.

Fig. 3. *Ellesmeroceras scheii* Gen. et Sp. nov. Cross-section of specimen, Figure 3 on Plate 27, from Bache peninsula.

Fig. 4. *Protocycloceras whitfieldi* Ruedemann. Vertical section of a specimen from Fort Cassin, Vermont.

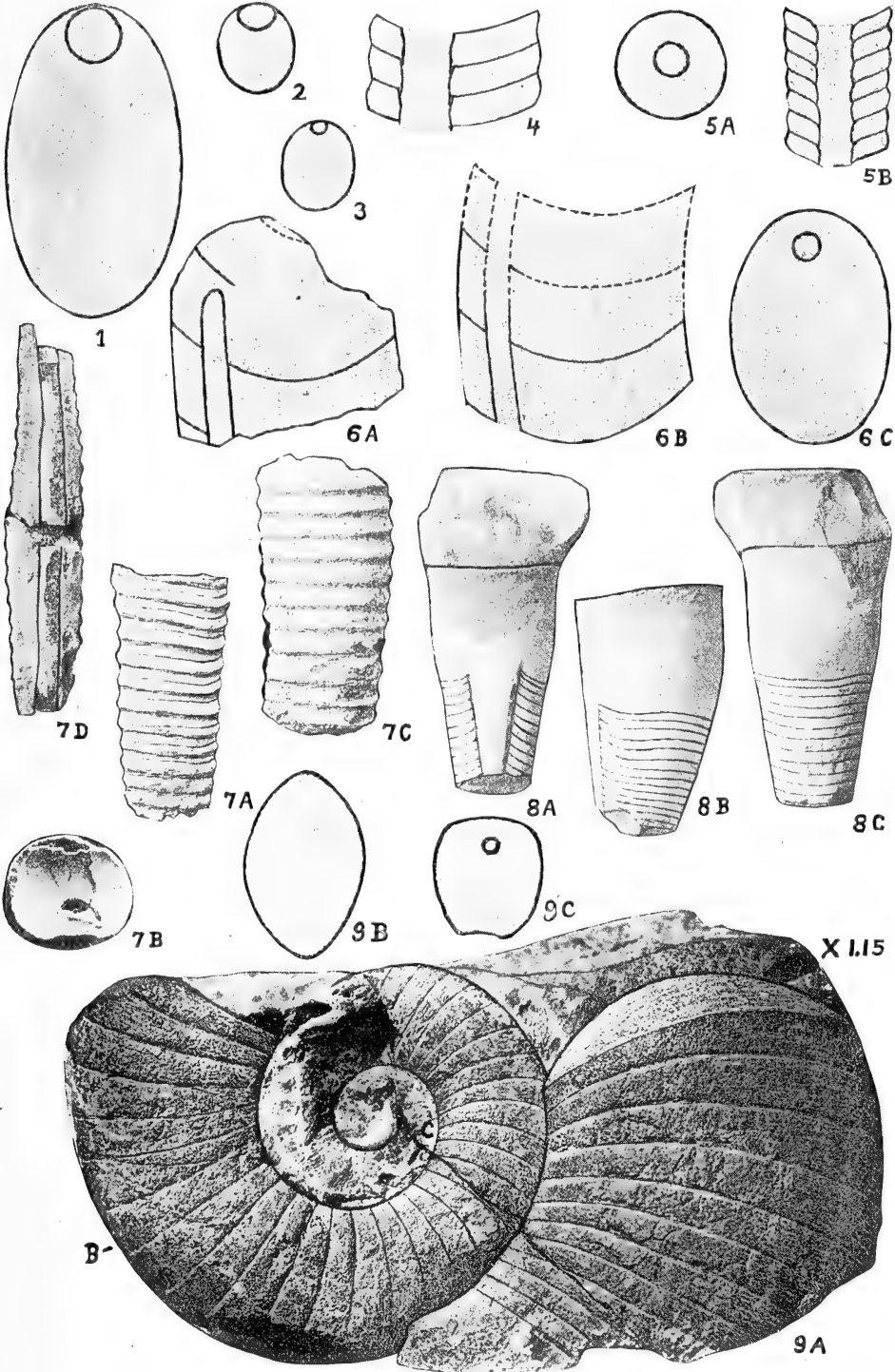
Fig. 5. *Protocycloceras* cf. *lamarcki* (Billings). *A*, cross-section; *B*, vertical section; both sections based on specimen, Figure 5 on Plate 27, from Bear Island, but restored in part.

Fig. 6. *Deltoceras* (?) sp. *A*, chiefly a longitudinal section through the center of the siphuncle, parallel to the dorso-ventral diameter. *B*, an attempted restoration, based on the preceding. *C*, cross-section, showing the siphuncle. Same specimen as Figure 6 on Plate 27. From Bear Island.

Fig. 7. *Protocycloceras lamarcki* (Billings). *A*, specimen No. 550a of the type series, showing sutures of the septa. *B*, specimen No. 550b of the type series, showing the upper surface of a septum, with part of margin of siphuncle distorted by crushing. *C*, specimen No. 550c of the type series, showing sutures of the septa only near the base of the specimen. *D*, vertical section through the composite specimen 508 and 508a, showing the siphuncle. *A*, *B*, *C*, from Huntingdon county, Quebec. *D*, from Romaine on the Gulf of St. Lawrence. Of Canadian age. All specimens in the Victoria Memorial Museum, at Ottawa, Canada.

Fig. 8. *Eremoceras syphax* (Billings). *A*, ventral view, showing the large siphuncle. *B*, lateral view, with siphuncle on left. *C*, dorsal view, with pseudo-siphuncle made by tool-marks of the original cleaner of the specimen, formerly misinterpreted as the siphuncle. From Point Levis, Quebec, in strata of Canadian age. Type, numbered 819 in the Victoria Memorial Museum, at Ottawa, Canada.

Fig. 9. *Eurystomites* (?) *boreale* (Foord). *A*, lateral view of type specimen. *B*, incorrect cross-section, secured from cast of type at point *B* in Figure 9A. *C*, cross-section prepared from the original specimen, probably along the crack crossing the center of the type diagonally, as in Figure 9A; part of a figure drawn by Dr. F. A. Bather from the original specimen. From the Wellington Channel, in Arctic America, collected by Captain Inglefield. No. 96955 in the British Museum of Natural History, in London.

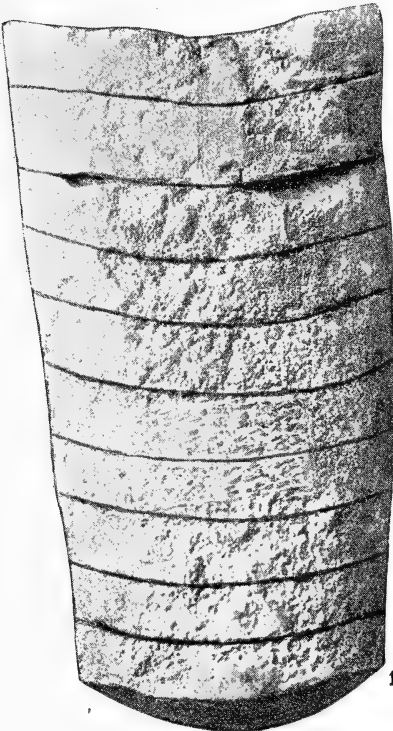


#### PLATE XXXIV

Fig. 1. *Leurorthoceras chidleyense* Sp. nov. *A*, ventral side. *B*, lateral side. *C*, cross-sections at top and bottom of specimen, showing location of siphuncle at bottom. *D*, vertical section along dorso-ventral plane, showing siphuncle. From loose blocks of Black River limestone, found at Port Burwell, 20 miles west of Cape Chidley at the northern end of Labrador. No. 7923, Geol. Surv., Canada.

Fig. 2. *Leurorthoceras hanseni* Gen. et Sp. nov. Vertical section along dorso-ventral plane of same specimen as fig. 1 on pl. 30. The specimen was cut diagonally sufficiently to cause the siphuncle to appear narrower toward the top, though in reality it enlarges slightly in that direction. From the Black River limestone either on Boothia Felix or on King William Land.

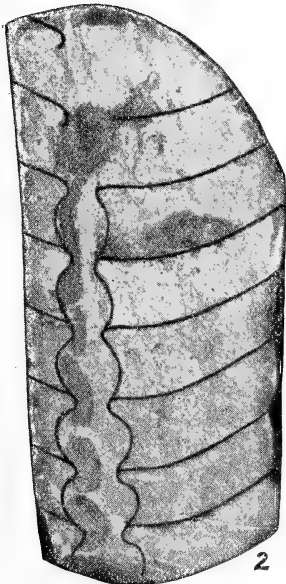
Fig. 3. *Orthoceras* sp. *A*, dorso-lateral view, with ventral side on right, not showing the maximum slant of the sutures of the septa. *B*, cross-section, showing the slight flattening of the ventral side and the location of the siphuncle. From the Valley south of Borgen in Goose Fjord in southwestern Ellesmereland. From strata comparable with the Keyser member of the Helderbergian. In the Palaeontologisk Museum, Kristiania: collected by Per Schei in 1902.



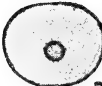
1A



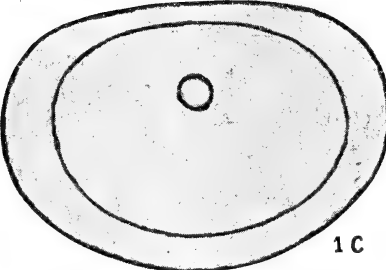
1B



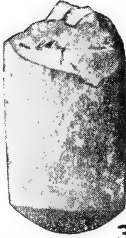
2



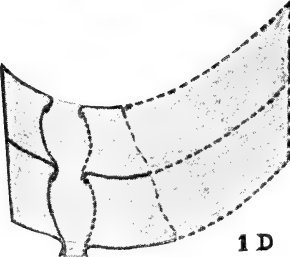
3B



1C



3A



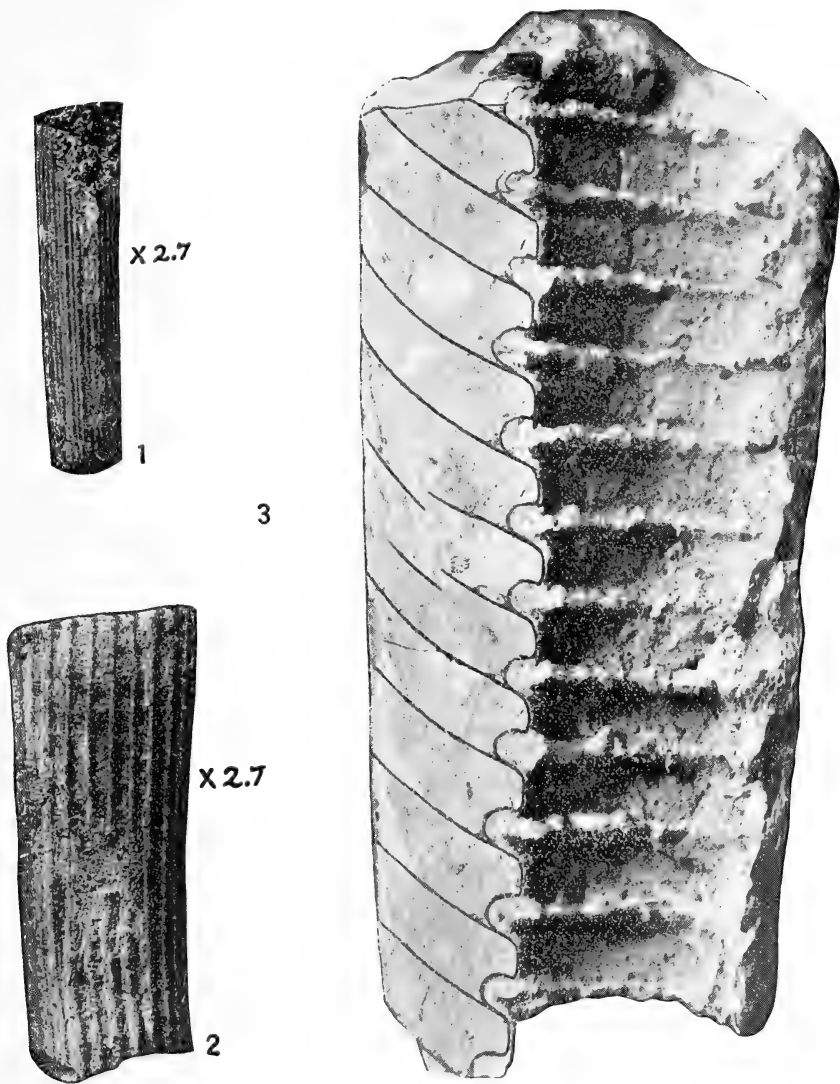
1D

PLATE XXXV

Fig. 1. *Kionoceras trentonense* Sp. nov. Lateral view, magnified 27/10. The alternation in size of the vertical riblets is shown best by the left half of the figure. From the original specimen represented by fig. 2 b, c, on pl. 56 of Pal. New York, 1, 1847. From the middle Trenton at Middleville, New York.

Fig. 2. *Kionoceras* sp. Lateral view, magnified 27/10. From the original specimen represented by fig. 3 on pl. 56 of Pal. New York, 1, 1847. From the lower shaly strata of the Trenton at Middleville, New York.

Fig. 3. *Actinoceras parksi* Sp. nov. View of a natural exposure of the interior of the siphuncle, showing on the left a polished vertical section exposing the septa, the long septal necks, and the relatively short connecting rings. From the Lower Rapids on the Shamattawa River, in northern Manitoba, west of Hudson Bay, in limestone of Ordovician age. No. 308 S, in the Royal Ontario Museum of Paleontology at Toronto.



AUG. F. FOERSTE

ARCTIC CEPHALOPODS



## REVOLUTION VS. EVOLUTION: THE PALEONTOLOGIST RENDERS HIS VERDICT

KIRTLEY F. MATHER

### I

Senators and bolsheviki, capitalists and members of the I. W. W., preachers and brick-layers, all, with few exceptions, are sincerely honest in their desire to improve the conditions, domestic, national and international, which determine the life and happiness of the individuals with whom they are acquainted. Most people would really be quite pleased, provided it did not entail too much labor or self-sacrifice on their own part, if the organization of society could be made more efficient and less wasteful, more subservient to the good of all and less profitable to the chosen few. We are still thrilled by the visions of the prophets of old and the propagandists of today with their dreams of a "new day" and a "new world." But just about there, our unity of mind and action ceases. Few among the real thinkers of any class are certain as to what these better conditions, which shall usher in the "dawn of the new day," shall be. And among these few, scarcely any two are agreed between themselves in regard to other than general and hazy ideas. More deplorable still, there are even more sharply defined differences of opinion among forward-looking men as to the method by which the reforms which they desire may be accomplished.

At bottom, it is really this difference of opinion as to method that distinguishes the Socialist with the Red Flag from the Republican with the Stars and Stripes, or the priest with his ritual from the evangelist with his sawdust trail. The distant goals which each envisions, although by no means coincident, at least have the merit of location in the same quarter of the universe; but the roads which are suggested as proper avenues

of approach to those comparatively adjacent goals are not even approximately parallel. The aims are similar, but the routes are various.

In general, would-be reformers—and that of course includes all adolescent or adult humans of sound or unsound mind—fall readily and naturally into two classes: those who believe in revolution, and those who believe in evolution. Each of these classes may be further divided into two sub-classes, dependent upon the reformer's notion of the forces which must be relied upon to accomplish successfully the desired result; reliance may be placed on the one hand upon human and natural forces, on the other upon suprahuman and supernatural.

Among those who believe in revolution, there are in the one group our inconoclastic brethren who have faith in the ability of the proletariat not only to overthrow the bourgeoisie but to perfect a new and beneficent organization of human affairs, which shall rise phoenix-like from the red flames of the blazing ruin of things-as-they-are. And on the other hand, in the same broad class of believers in revolution, there are those religious zealots who confidently await a day of destruction and judgment, when suprahuman forces shall be loosed in supernatural ways, and in the twinkling of an eye our present failure of a world shall be swept aside to make way for "the new heaven and the new earth."

In the ranks of the evolutionists, a similar cleavage is apparent. Some believe that the forces long operative, and even now operating, within the world are competent eventually to win mankind through to the high goal which seems to be set for him; that the Administrator of the Universe—to use Dr. T. C. Chamberlin's apt phrase—is powerful enough to make right forever triumphant without resorting to catastrophic destruction of the majority of his subjects. Others, impressed with the might of the quiet but constant forces of evolution and convinced of the futility of revolutionary expedients, fail to find the hope of better things in the present trend of affairs; rampant greed and unalloyed selfishness, eternal competition and bitter struggle, ever recurring tragedy, these seem to be the constant

companions of the evolutionary process from which the hit-or-miss method of Nature may never permit mankind to escape. For the disciples of evolution, who are thus led to believe in the impotency of natural laws and human worth, the future must indeed be black with despair.

Then, which shall it be? Evolution or revolution? Human ability and natural processes or suprahuman forces and supernatural power? Obviously, the question is far from being merely academic. One's whole philosophy of life, one's allegiance to the myriad welfare organizations of the land, one's alignment on the foremost political and social questions of the day, all these and more depend upon the answer. Nor is it a question which can be long postponed. So insistent has the clamor of the revolutionists become, that it penetrates even to the sequestered laboratory of the paleontologist and bids him rise from his study of fossil shell and petrified bone to give ear to the babel of twentieth century voices. And not unwillingly does he join the debate; for when it comes to a question of evolution who is there better fitted to make response than he who has visualized the stream of life which pulsed along the channels he has traced from those far-off Cambrian days until now?

Consider the lilies of the field and the birds of the air, the fishes of the sea and the creatures of the land. Retrace with the student of ancient life the long road that leads to man; watch the "phantoms behind us" marching step by step along that road. Search out the milestones of the past that mark the successful accomplishment of the great forward movements in life. For these creatures of the vanished ages, who have left the story of their lives recorded in the rocks of the earth's crust, are our kinfolk. Their problems are ours; our problems are but theirs. They have blazed the trail for us. The route to success and progress and "better things," which they found, is still open. The paths to failure, which they trod, are today as fair to look upon and as fatal to pursue as they have ever been.

## II

Had you asked a paleontologist of two or three generations ago these questions which we are now propounding, the chances are he would have replied unhesitatingly that life had progressed in the past by virtue of a succession of violent and tragic revolutions. For this was the belief and teaching of Cuvier, Lord of France, and one of the greatest of the founders of the science of Paleontology. Embedded in the gypsum quarried from the hill of Montmartre, now included within the limits of the city of Paris, Cuvier had found remarkably well preserved fossil bones of animals which he correctly inferred had been living in that region at the time the rock strata in which they were entombed had been accumulated. His knowledge of living creatures from all parts of the world was unusually extensive, and he clearly saw that these relics of the past represented animals quite unlike any known existing ones. They must be members of vanished races, swept out of existence in the prime of life by some overwhelming catastrophe such as the inundation of the sea over a subsiding continent, but whose remains had been fortunately preserved and were now displayed in Nature's vast museum. Perhaps the very floods of sea water from which the gypsum had been precipitated had also drowned the hapless inhabitants of the land, whose bones were buried on the sea floor.

Thus arose the doctrine of "catastrophism," a doctrine which was subsequently expanded until it enthroned the principle of revolution as the prime factor in the forward march of life. In the minds of Cuvier's followers, during the earlier half of the nineteenth century, it was the general belief that the cataclysms were world-wide, and that the slaughter of the older assemblage of animals and plants was followed by the special creation of a new and more improved group of creatures to inhabit the vacant spheres of activity. D'Orbigny, for example, taught that "twenty-seven times in succession, distinct creations have come to repopulate the whole earth with its plants and animals after each of the geological disturbances which destroyed everything in living nature."

Or, if the idea of numerous "distinct creations" is somewhat repugnant because it leaves open the way for the flippant suggestion that the Creator was not at first an expert artisan but required a lot of practice before he became sufficiently adept to perform his functions properly on a certain Saturday in the year 4004 B.C., the theory of catastrophism may be slightly amended. Let it be supposed that the devastating cataclysm was not quite world-wide, but that individuals here and there escaped to become the progenitors of the new assemblage of living creatures. This was apparently about what Cuvier really had in mind. In times of excessively arid climate there would somewhere be an oasis where a few favored individuals would escape the parching drought. When a glacial episode threatened to freeze the inhabitants of land and sea and spread a mantle of Arctic snow and ice over all the face of the earth, the climatic pendulum would be reversed just in time to save a dwindling minority to serve as seed for repopulating the ice-freed lands. Volcanic fires and earthquake shocks ordinarily would not completely devastate all inhabited places of the earth's crust at any one time; somewhere a few individuals would escape to provide descendants capable of returning to the wasted lands when the cataclysm had ceased. Tyre and Sidon went on their wicked way unscathed when fire from heaven rained down upon Sodom and Gomorrah, you will recall. Or perchance, safety from inundating sea or deluge might be found upon a high plateau or mountain top, such for example as Mount Ararat.

Thus by comparatively easy stages we might shift from the camp of Cuvier and d'Orbigny to another school of old masters in the science of Paleontology, among whom Sir Charles Lyell was foremost. Long before the time of Darwin, this group of scientists had come to believe in evolution of one sort or another and pinned their faith to the doctrine of "continuity." They noticed that there were certain "long-lived" species of animals and plants, whose remains were found unmodified in formation after formation regardless of the catastrophes which might have occurred in the intervals between their deposition. On the coast of Wales at the present time, for instance, certain

brachiopod shells which weather out of rocks dating back to the very oldest of fossiliferous strata are scarcely distinguishable from the shells of living brachiopods washed ashore by the waves which are daily exhuming the relics of antiquity from the cliffs against which they dash into spray.

Again, these believers in the continuity of life, regardless of local disturbances, adversities and cataclysms, called attention to the fact that the fossil remains of successive groups of plants or animals were as a rule indicative of creatures only slightly modified from those which had preceded them. Abrupt and sweeping changes in the assemblage of living beings were apparent whenever there were gaps in the record of life, but when the missing chapters were supplied by more extensive study the vital stream was shown to have been flowing on its way unbroken. Proof was not lacking that the presence of an altogether different assemblage of fossils in two successive series of rocks was due to the migration into that locality of creatures who had been slowly developing elsewhere. The pulse of life might beat a little irregularly now and then, but never had it been entirely suspended.

Gradually this notion of continuity of life, regardless of seeming interruptions in the record, gained sway, and at the present time there are no paleontologists who entertain any other idea of organic development. But still our question is unanswered. Granting the unbroken flow of the stream of life, what part in the progress of that stream has been played by the rapids and cataracts? Have they been essential to its onward flow, or are they only spectacular displays, actually of less importance than the quiet reaches where the deeper waters move?

### III

The close of the Paleozoic Era—that long interval of ancient time during which invertebrates and fishes, with later the addition of amphibians and reptiles, were the only animals upon the earth—was marked by a series of adverse episodes so disturbing in their influence upon plants and animals that it brought about what is commonly called a “revolution” in the organic

world. Episode number one in the thrilling serial was a crustal movement which crumpled the outer layers of the earth into a long line of mountain ranges stretching across what is now Belgium, Northern France and Southern England. These, the "Paleozoic Alps" of Europe, have long since been worn down and washed into the sea, but the roots of the quondam cordillera still remain. This crustal crumpling was accompanied by a general upward movement of all the continents and a deepening of the ocean basins so that shallow seas which had hitherto spread out over a large proportion of the continental platforms retreated oceanward and left dry land or broad swamps where great bays and estuaries had been. It so happens that the overwhelming majority of marine organisms are adapted to life in the shallow seas alone. The greater part of the deep sea is nearly or quite devoid of life; only in the upper hundred fathoms and on the ocean floor are living creatures found. More than 95 per cent of all the inhabitants of the sea are confined to the shallow coastal waters between the strand and the hundred-fathom line. Previous to this crustal disturbance, the area of this particular zone had been very large and life had expanded and multiplied therein. Now, its area was reduced to a small fraction of its former extent, and the severity of the struggle for existence that must have taken place within this dwindling zone can well be imagined.

Then followed episode two. Gradually the climate of the world changed from its former agreeable warmth to Arctic cold. Great ice sheets, far more extensive than those of the much later and better known epoch to which the name "The Great Ice Age" is frequently applied, formed upon the lands and spread in all directions. In India and in Bolivia these glaciers reached even within the tropics, while in South Africa and Australia they were only slightly less extensive. The life of land and sea, alike, was diastrously affected by these adverse climatic conditions, and the end of the Paleozoic Era marks also the termination of scores of genera and families and even of many orders of animals and plants.

Episode number three was somewhat similar to that which had opened this chapter of earth history. Its chief event was the building of the Appalachian Mountains, which in their youth were mighty ranges not unlike the Rockies of British Columbia. The areas of hospitably shallow seas were still further reduced, and vast sandy plains stretched monotonously across the states of Texas, Oklahoma and New Mexico. Deserts, equalling the Sahara in magnitude and aridity, existed in parts of Europe and North America where today are fertile farms and majestic forests. The tribulations heaped upon the creatures of the land became even more numerous than before, as the humid areas of temperate climate were still further diminished in extent and number. The physiographic and climatic changes wrought during these three episodes in earth history could not fail to leave their indelible imprint upon the entire population of the globe, composed as it has always been of individuals quick to respond to modifications in their geographic environment.

With the crumpling of the Appalachians, the mighty forces pent within the body of the earth seem to have spent their energy. Equilibrium of the opposing stresses was once more attained. The close of the Paleozoic Era was followed by another long era of comparative stability of the earth's crust. Gradually the normal temperate climate of the globe was restored; once more, broad shallow seas crept over the lower portions of the continental platforms; again, the regions of land and sea most hospitable to life expanded until they covered a large proportion of the planet; a long era of prosperity for the earth's inhabitants was ushered in. This, the Mesozoic Era, the time of medieval life, is referred to as the Age of Reptiles, because during it the animals of this class aspired to the rulership of every domain of life, the land, the sea and the air.

What were the effects of these revolutionary episodes upon the creatures subjected to them? Were they for good or for evil? Space forbids a full discussion of the problem; we may concentrate our attention upon a single class of animals and take their experiences as typical of all. And I choose from among the many available illustrations that afforded by these

self-same reptiles whose numbers were so great during the age which followed, for to me their story is fraught with the greatest interest.

D'Orbigny taught that the reptiles were created immediately following the world-wide cataclysm, into which the three episodes enumerated above were exaggerated, as a part of the process of re-peopling a world from which all life had been annihilated. But the researches of Williston and others have revealed the fact that the reptiles had been in existence long before these staggering events, had indeed progressed far along their varied and spectacular career before the close of Paleozoic time. Already they had deployed into several distinct orders; already more than one strain had risen to the climax of its career, tasted the fruits of success in its chosen line, and passed away, blotted out of existence in the never-ceasing competition of rival races, or failing utterly to withstand new and adverse conditions in their environment.

Take for example the curious "fin-backed lizards," known to science as Pelycosaurs. From each vertebra of their spinal columns a long bony spine grew vertically upward, and, the whole series sheathed in leathery integument, formed a "fin" along the middle of their backs. Successive genera are known with increasingly high fins until the climax of this reptilian strain was achieved in a creature whose fin was twice as high as his back even when his body was lifted as far from the ground as was possible for his stubby legs to elevate it. His fin spines were more than two feet long and each was decorated by short spicules of bone growing horizontally at right angles to the long bony column. Just what purpose was served by these bizarre appendages is not known; whether for decoration, defense or other practical use, it matters not in the present discussion. The important fact is that this entire reptilian race was swept out of existence at the close of the Paleozoic Era and left, so far as now known, no descendants to make their contribution to the Age of Reptiles.

Again, there lived at this time one group, the Mesosaurs, who had become entirely adapted to life in the fresh waters of rivers

and lakes. They are among the first of many creatures who forsook the land, modified their legs into swimming apparatus of one form or another, mimicked the fishes in the shape of their bodies, and returned to the water which their remote ancestors had long before deserted to invade the new terrestrial domain. Interestingly enough, these fresh-water reptiles are known to have lived during the closing epochs of the Paleozoic Era only in South America and South Africa; how they travelled from the one continent to the other, they could not exist in the salt water of the sea, is one of the unsolved problems of the paleontologist. They, too, had their day and ceased to be, and their whole life history was closed before the Age of Reptiles began.

But several of the reptilian strains were more successful or more fortunate; they persisted, to become not only the progenitors of the varied saurian masters of the Mesozoic Era but of the higher class of birds and still higher mammals as well. Clumsy, crawling creatures they were, with much bone and little brain in front of their squat shoulders. Heavy in body, short in leg, many of them could little more than drag their trunks over the sand or through the mud. For some of them the vast arid tracts seemed purposely designed, and there they multiplied in number; deployed into several different evolutionary strains and slowly, conservatively perfected that complete adaptation to the dry land which was necessary to the further progress of life. Truly reptilian in habits, the cold blood which coursed sluggishly through their veins was not shocked by the icy drafts of the glacial climates. The disastrous episodes which closed the Paleozoic Era left them unscathed; the rush of the stream of life swept them forward to the high destiny which they realized in the Age of Reptiles.

But their success was not achieved as a result of the revolutionary events which mark the transition between those two eras. They had already won for themselves their leading parts in the drama of life. Long ages of quiet unassuming preparation had preceded those spectacular moments. The slow and steady progress which they were making seems simply to have been accelerated by the very adversities of that comparatively

short interval of upheaval. The revolution was a success only because of the preceding preparatory development which progressed so deliberately and inconspicuously that it entirely escaped the attention of the earlier students of ancient life, thrilled as they were by the apparently abrupt and sweeping changes which the revolution wrought. Those "reforms" were merely the climacteric fruition of a lengthy period of preparatory evolution.

Examples without number, drawn from other classes of animal and of plant life at this same milestone in the progress of life, parallel this one. The same story recurs again and again as other milestones are passed. We may pause for but one other illustration.

The transition from the Mesozoic Era to the Cenozoic Era, the era of modern life, is marked by physiographic and climatic changes not unlike those which characterized the transition just sketched. Once more, the stresses slowly accumulating within the rigid body of the earth were piled one upon another until they could be no longer resisted; the pent-up energies must be released as before. But the chief scenes of the drama were staged in other places; the most conspicuous milestone is found where the American Cordillera rears its cloud-swept peaks from Alaska to Cape Horn. This mightiest of all but one of the modern mountain systems dates its birth from the close of the Age of Reptiles. The travail which brought it into existence was marked by violent volcanic outbursts on a gigantic scale; Vesuvius, Stromboli, Krakatoa, Pelee and Mauna Loa, all crowded into a single county and set in simultaneous eruption would perhaps give some idea of the events which constitute episode one of this second serial. Again, there was a general elevation of the continental platforms and a withdrawal of the shallow seas to the newly deepened ocean basins. Again, there were far-reaching climatic changes; even another glacial episode, if, as seems probable, the glacial deposits recently discovered in Colorado and British Columbia date from this time. Again, there was a second mountain-making crumpling of the earth's crust, this time concentrated in the same cordillera

which had come into being as a result of episode one and therefore much more difficult of interpretation. All in all, the changes in the physical environment of the earth's inhabitants were nearly or quite as sweeping as those which resulted in the striking modifications of life as it passed from the Paleozoic to the Mesozoic types. And, as before, the living creatures responded to these changes so completely that another "revolution" is recorded in the older text-books. In a word, the host of reptiles which had dominated land and sea and sky were swept into oblivion and their places were promptly assumed by mammals, the most advanced of all creatures. As a consequence, the Cenozoic Era is known as the Age of Mammals.

Again, let us enquire more particularly into the history of the group of animals which seem to have profited most by this "revolution." To state it briefly, the story of the mammals at this time is almost an exact parallel to that of the reptiles at the close of the Paleozoic Era. Instead of having been created subsequent to the devastating catastrophe which was believed to have left an uninhabited world for them to people, we now know that they had long been in existence. The first relics of mammalian life date far back in the Age of Reptiles. Before its close there were countless hordes of small warm-blooded creatures, competing, in spite of their insignificant size and by virtue of their superior brain power, with the gigantic and powerful but clumsy and unintelligent reptilian masters of the world. This very competition, carried on during at least three geologic periods, gave them strength and cunning not only to outwit their opponents but also to adapt themselves even to such adverse environmental conditions as surrounded them during the geographic revolution inaugurated by the first birth-pains of the American Cordillera. Far more ready to profit by its changes, because of their mobility, their warmth-preserving pelts and their intelligence in securing new food supplies, than were the reptiles, they succeeded where their competitors failed. Coincident with the return of the balanced conditions which lead to long periods of comparative stability of the earth's crust, the mammals promptly acceded to the

many thrones left vacant by the reptiles, unable to withstand the adversities of climatic and physiographic change coupled with the ever-increasing ability of their mammalian foes, and soon dominated land and sea. Soon thereafter they even aspired to the dominion of the air, but in that sphere of activity they have thus far failed to rival the birds.

The conclusion seems unescapable that again the revolutionary achievement was merely the climax of a long slow upward climb. Had not the preparation of the mammals been complete they could scarcely have seized so successfully upon the opportunities which opened before them at this time. The conclusion is further fortified when we note that the immediate ancestors of mammals, the theriodont reptiles, had been in existence before the close of the Paleozoic Era, but, though they foreshadowed the mammals in many important particulars of body structure, they apparently made no marked response to the environmental changes occurring at the close of that era. The long preparatory period had but begun for the mammalian strains; not yet had they attained the abilities sufficient to profit by those changes; that "revolution" gained them little or nothing, simply because they were not ready to take advantage of it. The inauguration of the mammals as the lords of the earth must wait, regardless of "revolutions," until the offspring of those theriodonts had by the long slow processes of evolution completed the training prerequisite to that proud position.

This seems to be the law of life. Revolutions are of little avail unless preceded by long and generally agonizing periods of preparation. Slowly progressive evolution may lead to a spectacular climax of fruition during a moment of organic upheaval, but the attainment is the result of the preparatory development, not of the revolutionary forces. Time and again, upon the long road so painfully traversed during the geologic eras, important milestones have been passed, great upward steps have been achieved, unaccompanied by anything remotely resembling a "revolution," but never, so far as I am aware, has any group of animals or plants gained advantages at times of

crisis without long antecedent training which paved the way to their success. In the stream of life, the cataracts and rapids are but spectacular manifestations of the fundamental forces which gain their ends effectively in the slowly moving reaches where the quiet waters irresistibly flow.

## IV

There is a wide-spread opinion "that the idea of the continuous development of the life of man on the earth was something foreign to the mind of Jesus; the idea of catastrophe, it is contended, was ever present to him. On the wreck of the world his Messianic kingdom was to be established." It is the view held, consciously or unconsciously, by the great majority of churchmen throughout all Christendom. Opposed to it is the concept, rapidly gaining adherents in the present generation, that the Man of Galilee put no trust in destructive revolutions, but had a firm and sure faith in the evolutionary forces quietly operating within the lives of men. The issue is sharply defined. Did the Great Teacher instruct his hearers in the dogma of revolution or in the doctrine of evolution, in the necessity of world-destroying upheavals or in the efficacy of quietly progressive growth, in the purification of the world by fire and sword or in the attainment of man's high destiny along the less spectacular roadway of spiritual and mental development?

Consider for a moment the remarkable assemblage of the "Parables of the Kingdom" in the thirteenth chapter of Matthew's gospel. Here are intermingled the evolutionary parables of The Sower, The Mustard Seed, The Leaven, each with its unmistakable emphasis on growth, development, progress from within, and the revolutionary parables of The Tares and The Net with their references to the harvest time of reward and destruction, to the end of the world in catastrophe and upheaval. The Founder of Christianity was a master in the art of finding and clinging to the happy medium of carefully balanced judgment. Never was he guilty, as have been so many of his followers, of pushing a great truth to a ridiculous extreme. And upon this greatest of Christian themes he has carefully chosen

and maintained the middle ground. Progress, even to the attainment of the new heaven and the new earth, even to that glad day when all men shall be enrolled in the kingdom of heaven, is the result of growth and evolution; but the long summer of development bears fruit in the autumn of harvest; the era of quiet progress paves the way for a climax of fruition; long ages of slow preparation, so slow and inconspicuous as to appear negligible to the superficial observer, finally achieve results with startling suddenness. Lest his hearers spring to arms with a frenzied desire to sweep their fellowmen without delay into his new kingdom under penalty of death if they refuse to enter there, he calmly, dispassionately speaks of the seed-time and the leaven, the gradual growth of the tree and the long summer of increase. Lest they become impatient of delay, discouraged with the apparent paucity of achievement, he turns their attention to the harvest-time when the results of growth are tested and rewarded according to their merits, he speaks of the closing moments of an era when the pulse of life is accelerated and preparatory development attains fruition in new opportunities for further progress.

It is as though the humble Carpenter of Nazareth had with the student of life development surveyed the river of life and had seen it sweeping quietly, irresistably onward to plunge in a cloud of spray over the brink of a cataract, then to stagger for a moment before it regains its sense of direction and slips silently ahead into another long reach of steady movement. The lesson from the past is clear. The progress of life has been a result of evolution and of growth, quiet, unassuming, slow; but ever and again progress has been revolutionary in its nature, and by virtue of abundant preparation there has come a time of swift attainment, a climax of success. Revolutions in the past have been truly catastrophic for those organic strains whose preparation has been inadequate, but in the progress of life as a whole they have been merely minor incidents, a quickening of the pulse, an acceleration of the continuous process of evolution.

## V

From the paleontologist's vantage point on the reviewing stand, the creatures of the earth appear in this twentieth century to be approaching another milestone in their progress. There are rapids and cataracts just ahead; once again, the stream of life is gathering its energies to leap forward with increasing velocity until it plunges swiftly over the brink of another falls. A crisis in life development, fully as critical as those which opened and closed the Age of Reptiles, is close at hand. Survival values once again have changed, but the same principles which selected certain groups of animals to weather those "revolutions" of the past will doubtless guide certain of the existing creatures through the dangers in the offing. The crisis recorded in the rocks of latest Paleozoic Age, was forced upon the land animals by changes in climate and environment; it was successfully passed by creatures who specialize in the adaptation of their bodies to cold and drought, and who escaped from the crowded confines of the sea to the almost uninhabited silences of the land. The "revolution" involved in the dethronement of the reptiles and the exaltation of the mammals at the close of the Mesozoic Era was likewise precipitated by external changes over which the mammals themselves had no control; it bettered the condition of creatures who specialized in the care of their young and the use of their brains. Each group which prospered had for some time displayed the very characteristics which proved efficacious in the time of stress; the "revolution" afforded the opportunity for the testing and the rewarding of the products of progressive evolution.

The crisis of tomorrow, already imminent, is likewise in its real essence the result of external conditions over which man has so far displayed no control. The world has lost its corners and shrunk into a neighborhood; but man is not to blame because ocean highways link its farthest islands, and mountain barriers fail to subdivide its lands. The resources of the earth are proving inadequate to support a large population of idle rich or idle poor, without an excessive load being placed upon the

workers; but it is not the fault of man that the stores of iron ore are limited, and the acres of tillable land are numbered. As in the past, so in the twentieth century, the impelling forces of progress are inherent in the environment; the response must be dependent upon virtues intrinsic in the creatures who are to be thus tested. Some will undoubtedly be found wanting; for them the penalty has always been either extinction or stagnation. Others—and in the past it has generally been a minority—will respond with habits that will prove to be their salvation; they, and they alone, will profit by the revolution.

To prophecy is always to incur the danger of post-mortem pillorying. But it requires no unusual acumen to see that this next milestone in the progress of life will be safely passed only by those who specialize in the art of coöperation, as opposed to selfishness, and in the practice of kindly thoughtfulness for others, regardless of their color, race or creed.



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Edited by

KIRTLEY F. MATHER

Permanent Secretary, Denison Scientific Association,  
Granville, Ohio

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# A REVIEW OF THE BIOLOGY OF SEX-DETERMINATION<sup>1</sup>

SIDNEY I. KORNHAUSER

## 1. PREVALENT IDEAS

The mechanism of sex-determination has been a matter of speculation since time immemorial. Many erroneous and impossible ideas remain even today in the mind of the layman. The speculations may be gathered in three groups according to whether belief is held (1) that the sex of the offspring is pre-determined in the egg, (2) that sex is determined at the time of fertilization, or (3) that sex is not determined until after the zygote has been formed.

All of the older experiments on sex-determination were based on the third supposition. It was believed that by varying the nutrition of the developing embryo one sex or the opposite would result. This belief was even applied to human beings. In experiments upon tadpoles definite results were believed to have been attained, but we now know that the death rate in these experiments was so large that the results may be explained by a differential mortality.

Others held that the age or vigor of the parent affected the sex ratio, the older or the more vigorous of the two parents tending to impress its sex upon the offspring.

Another belief, and one still held by many, regards the freshness or staleness of the egg as important. An egg shortly after ovulation tends to produce a female, while an egg which has remained in the oviduct some time would tend to produce a male.

The idea that two types of eggs are formed is not altogether new. Thus, entirely without biological foundation, theories

<sup>1</sup> A lecture delivered before the Denison Scientific Association in October, 1921.

were propounded that one ovary gave rise to male-producing eggs whereas the opposite ovary gave rise to female-producing eggs. Equally valid was the theory that one testis gave rise to male-determining spermatozoa and the opposite testis gave rise to the female-producing spermatozoa. Two sorts of eggs in equal numbers and one type of sperm would give a 50:50 ratio; also two sorts of sperm in equal numbers and one type of egg would give a 50:50 ratio.

These latter ideas are found in modern theories of sex-determination, but today they are based on an actual biological foundation through the use of the microscope and breeding tests.

## 2. CHROMOSOMES AND SEX

Modern theories of sex-determination hold to the first and second propositions, stated in the first paragraph of this article. If there are two kinds of eggs, male determining and female determining, then the sex of the individual is already fixed before the sperm nucleus has united with the egg nucleus. At least we may say that with the extrusion of the polar cells, the mechanism has been brought into play. If there are two kinds of sperm, male determining and female determining, then sex-determination depends on the type of sperm uniting with the matured ovum, and we may say that sex is determined at the time of fertilization.

Our present day stand on these questions is based entirely on direct observation, both cytological and experimental. In 1902, McClung discovered an unpaired chromosome in the testes of certain Orthoptera and this chromosome he called a sex-determiner. This observation, together with the association of this chromatic body with sex-determination, was of primary importance and it opened up a new era in cytological work. Volumes have been written on the mechanism of sex-determination since 1902, and even at the present time facts on this subject are being added almost daily.

In many groups of animals there is an unpaired chromosome in the male, which is called the X-chromosome. This can be seen in the somatic cells, in the spermatogonia and in the sperma-

tocytes (fig. 1). We now know that the X-chromosome is paired in the female cells, both somatic and germinal. In

### Diploid Group, Male

### Diploid Group, Female

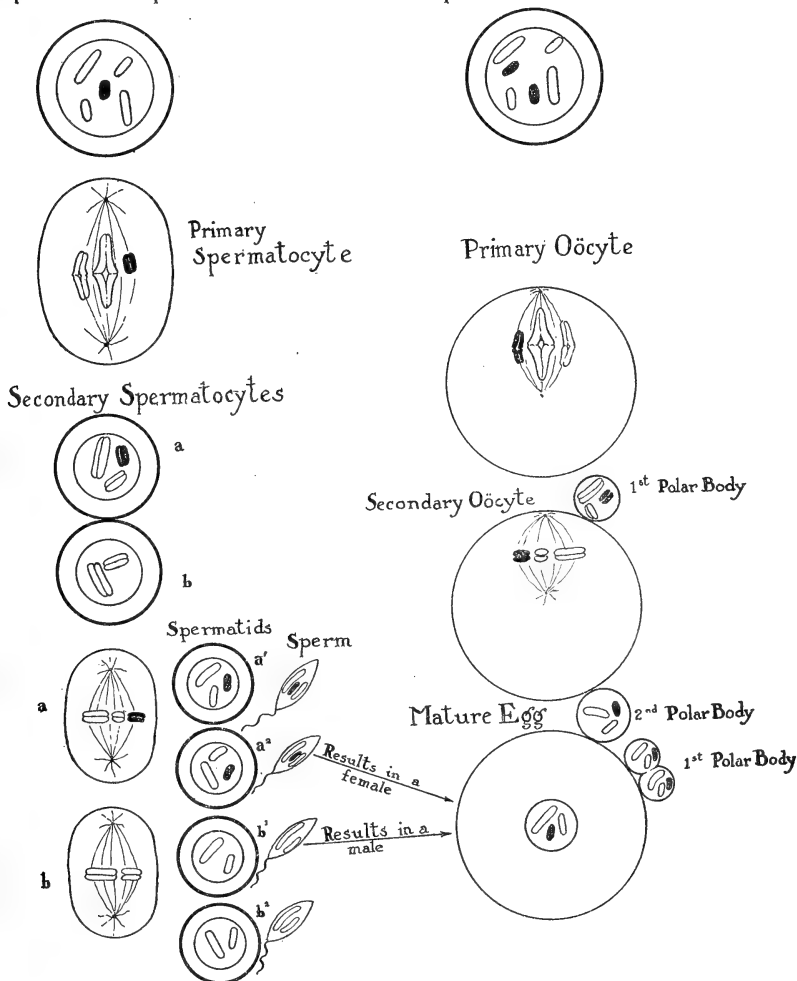


FIG. 1. SIMPLEST KNOWN MECHANISM OF SEX-DETERMINATION

The X-chromosome is shown as black; the autosomes are in outline

spermatogenesis the autosomes pair to form tetrads. In the first spermatocyte division the tetrads are reduced to dyads and the X-chromosome generally passes undivided to one second

spermatocyte. In dividing again into spermatids, this second spermatocyte (fig. 1, a) gives rise to X-bearing cells which form the female-determining spermatozoa. The sister second spermatocyte which did not receive an X-chromosome gives rise to the two male-determining spermatozoa. A zygote which receives two sets of autosomes and two X-chromosomes is a female; a zygote which receives two sets of autosomes and one X-chromosome is a male. Since in general both types of sperm are formed in equal numbers, the chances of a male- or female-determining spermatozoan reaching the egg in the process of fertilization are equal, and in general 50 per cent of the resulting zygotes are male and 50 per cent female.

The foregoing case is the simplest mechanism known. While this is a fundamental type, still there are many variations of the mechanism. Thus the X-chromosome may have a Y partner in the male cells. If  $n$  = one set of autosomes in a given animal, then we have the following combination in this case:

$$2n + XY = \text{male, and } 2n + 2X = \text{female}$$

In the spermatogenesis of such animals, two spermatids receive an X-chromosome and two a Y-chromosome, the latter being the male-determining spermatozoa. In other cases the X-chromosome may be represented by several discrete components; and it may or may not have a Y-chromosome associated with it in the male cells. Thus in *Gelastocoris*, an hemipteron, the male is represented by  $2n + 4X + Y$  and the female by  $2n + 8X$ . " $n$ " here equals fifteen, so the male diploid number is 35, and the female diploid number is 38.

Detailed studies of the sex chromosomes have brought out many interesting facts. The X-chromosome in some animals is attached to a certain autosome, as in *Culex* or in *Ascaris megalocephala*. When paired, as in the female somatic cells or in oöcytes, the X-chromosomes behave similarly to autosomes in mitosis and in the mitotic divisions and also in syndesis. Contrary to this, the unpaired X-chromosome of the male acts rather unlike an autosome in the spermatocytes. It fails to form a leptotene thread, generally appearing as a conspicuous karyo-

some. Very often it lags behind the anaphase autosomes in either the first or second spermatocyte division. The Y-chromosome likewise often fails to form a leptotene thread. In the growth of the spermatocyte, and in the maturation divisions, the X- and Y-chromosomes show considerable variation in degree of association. In the primary spermatocyte division of many Heteroptera the X- and Y-chromosomes divide independently. They then come into contact and separate reductionally in the second spermatocyte division.

We may now ask how the sex chromosomes are related to the autosomes. That the X-chromosome bears many genes for characters having nothing to do with the process of sex is known from breeding experiments. In the female the X-chromosomes, except where there are differences in size, cannot be distinguished from ordinary autosomes. Recent experiments, especially those of Bridges on *Drosophila*, indicate very clearly that there are specific sex-genes in the X-chromosome, which working in conjunction with the genes of the autosomes are capable of producing males or females or even intermediates in cases where the normal relationship is upset.

We are therefore entirely rid of the older idea that the X-chromosome is composed of a different kind of chromatin from that found in the autosomes and that the sex of the zygote depends upon the amount of X-chromatin it receives. Sex is now put upon a basis of specific genes.

The Y-chromosome until recently has not been known to carry specific genes for bodily characters. Indeed, this chromosome is generally regarded as merely a degenerate X-chromosome which has lost its sex-genes and most of its other genes as well. That it is essential to normal development in species ordinarily having it present was shown in the non-disjunction experiments of Bridges. Thus, male *Drosophila* without a Y-chromosome are sterile. In size the Y-chromosome may be as large as the X or it may be almost insignificant in comparison to it. In *Enchenopa binotata*, studied by the author, both the X and Y elements form threads in the leptotene stage of the primary spermatocytes. These threads are thicker than those of the autosomes and never

conjugate laterally, remaining in contact merely at one end. They are not widely removed from the autosomes in their activities and staining powers in the species. However, in other forms, such as *Anisolabis*, studied by the author, the Y-chromosomes may exhibit entirely different staining reactions from the X-chromosome. It may be looked upon as degenerate from a cytological standpoint.

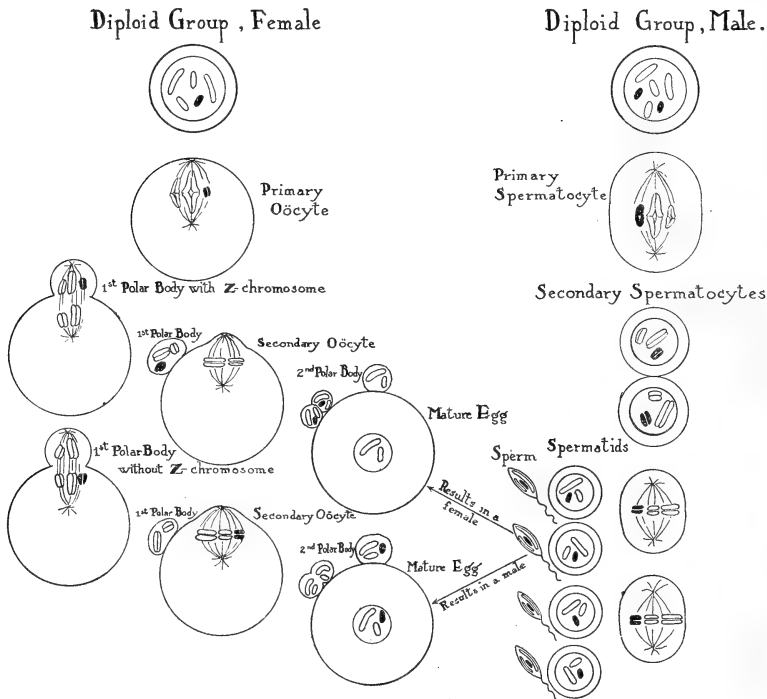


FIG. 2. MECHANISM OF SEX-DETERMINATION IN WHICH TWO TYPES OF OVA ARE PRODUCED

The Z-chromosome is shown in solid black

In many forms it is therefore not unlikely that, although there is no sex-determining mechanism visible to us with the aid of our best microscopes, nevertheless X and Y chromosomes exist, the Y-chromosomes being practically equal in size to the X-chromosomes and differing from them merely in the absence of specific genes.

The reverse of the foregoing mechanism described for insects and mammals is to be found in the Lepidoptera and the birds. In these groups the presence of  $2n + 2X$  or  $2Z$  (as the sex-chromosomes are here called) results in a male and  $2n + X$  or  $Z$  produces a female. These facts are well borne out by breeding experiments in both groups. The cytological basis is not so strong, for both avian and lepidopteran chromosomes are rather difficult to study.

In the moths definite results have been reached by Seiler and also by Doncaster, showing that two types of ova are produced. Those which extrude the  $Z$ -chromosome in the polar cell will when fertilized produce females, those which retain the  $Z$ -chromosome when fertilized will produce males.

It is obvious from the diagram, figure 2, that the sex of the zygote depends entirely upon the maturation of the ovum, the retention or expulsion of the  $Z$ -chromosome being the deciding factor. If in any way maturation can be controlled by factors exerting their influence either from within the egg itself or external to the egg, then sex ratios may be altered from the normal 50:50. Seiler has done this in the case of moths by varying the temperature. It also offers a possible explanation of such sex ratios as have been obtained by Riddle in his forced breeding experiments of doves, where females are produced in the latter part of the season from larger eggs and males in the early part of the season from smaller eggs.

### 3. COMPLICATED LIFE CYCLES

The most enlightening observations on the determination of sex through maturation are those in the aphids and phylloxerans studied by Morgan and von Baehr. Let us examine the case of *Aphis saliceti* of von Baehr. It is well known in these insects that fertilized eggs always produce females. During unfavorable conditions both males and females are produced by parthenogenesis, the males, however, always arising from smaller eggs. It has been shown that in these small eggs (represented at the extreme right in figure 3) a whole  $X$ -chromosome is extruded in

the formation of the one polar cell, leaving in the egg  $2n + X$  chromosomes (five in number), and that such an egg forms a male. In the larger parthenogenetic eggs no whole X-chromosome is extruded in the single polar egg given off, and the egg retains  $2n + 2X$  chromosomes (six in number) and develops into a female. In the spermatogenesis of these forms it was found that only one secondary spermatocyte develops, that which received the X-chromosome. Thus only two instead of four spermatids result from a primary spermatocyte and these are

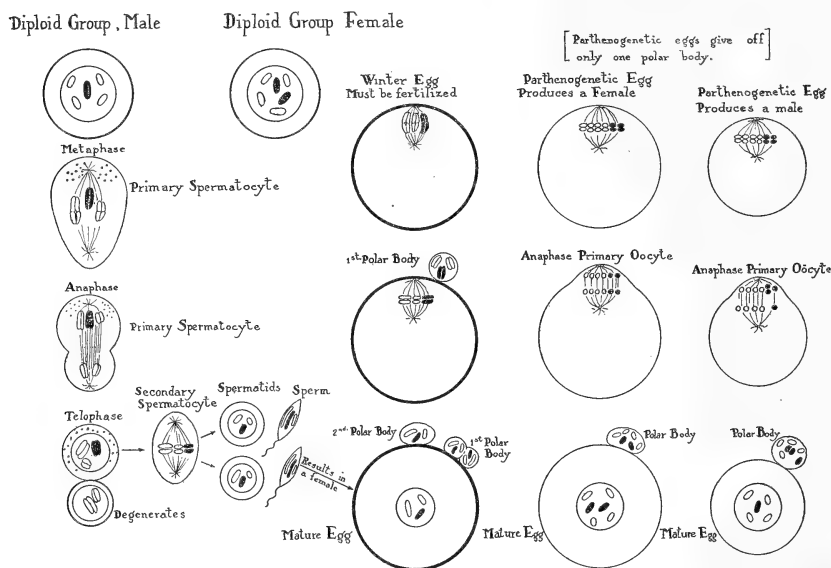


FIG. 3. SCHEME OF REPRODUCTION OF APHIDS AND PHYLLOXERANS

female-determining spermatozoa. In this case of the phylloxerans and aphids it would thus appear that maturation is in reality controlled by the size or composition of the egg.

It is rather unfortunate that the rotifers and daphnids are not such favorable cytological material as the homopterans for it is not at all unlikely that their sexual cycles rest upon a basis similar to that above described. In rotifers and daphnids the biological conditions are almost identical with those of the aphids and phylloxerans. Fertilized eggs give rise only to females,

whereas parthenogenesis may result either in females or males, the latter coming from smaller eggs. This is all the more interesting because both Whitney and Shull, working on rotifers, have by external conditions been able to alter the normal cycle and to cause the discontinuance of parthenogenesis, thus bringing on the production of male individuals and eggs which require fertilization. They have evidently through these conditions influenced the type of egg produced. The type of egg would then control its own maturation if the case were parallel to that of *Aphis* and *Phylloxera*.

In the Cladocerans, where parthenogenesis alternates with a sexual cycle and at least three kinds of eggs are produced (thick shelled, fat laden, ephippial eggs which must be fertilized; thin shelled, glycogen laden, parthenogenetic eggs, developing into females; and thin shelled, smaller parthenogenetic eggs, developing into males), the type of egg produced may be influenced by temperature and food, as was shown by Geoffrey Smith. It is not improbable that we may yet see in the maturation of these ova differences in chromosomal behavior correlated with each type of ovum and the sex of the resulting offspring.

Closely allied to the foregoing problem is the question of sex determination in the Hymenoptera. Even before chromosomes were known, Dzierzon postulated that males (drones) were formed from unfertilized eggs and females (workers and queens) from fertilized eggs. This has been substantiated nicely, both from cytological and genetical investigation. Newell showed in bee matings of Italian (grey) queens and German (dark) drones, and also in reciprocal crosses, that the male offspring of such matings were purely maternal while the females were hybrid in character. Cytological observations by Petrunkevitch and Nachtsheim have also established the validity of the Dzierzon theory. Coupled with this, observations on the spermatogenesis of Hymenoptera have revealed interesting results. The spermatogonia possess merely the haploid number of chromosomes. In order that this number be not further reduced in the process of spermatogenesis only one division of the chromatin takes place. In the bee the first spermatocyte division results in all the chromatin passing

to one centrosome; a minute degenerate non-chromatic globule is formed at the other pole of the spindle. In the second maturation division, the chromatin divides, but one of the spermatids is very small and degenerates. Thus only one instead of four spermatids is formed, and it contains the haploid number of chromosomes. Variations of this process are found in other Hymenoptera, resulting frequently in two spermatids from the larger second spermatocyte, each possessing the haploid number of chromosomes.

The possibilities of sex production through parthenogenesis are many. Reduction to the haploid number, or the elimination of a whole X-chromosome, may produce a male, whereas the elimination of one maturation division may allow the egg to retain the diploid number and develop into a female. Still further possibilities are offered in cases where either the retention of the Z-chromosome or its elimination is of vital concern in the resulting offspring. Goldschmidt has reared both sexes from unfertilized moth eggs.

#### 4. POLYEMBRYONY

Closely allied to the subject of the chromosomal basis of sex are the facts of polyembryony. Where more individuals than one are formed from an ovum they are almost invariably of the same sex. The classical examples are parasitic Hymenoptera, principally of the families Proctotrypidae and Chalcididae, where often thousands of individuals result from a single egg. Other examples are the quadruplets formed in the nine-banded armadillo, and identical or monochorial twins in man and other mammals. In the case of mammals the type of sperm (either with or without an X-chromosome) is undoubtedly the deciding factor. Providing then that all the chromosomes of the zygote divide normally, the sex of the resulting individuals must be the same, and they will be genetically identical. In the Hymenoptera the sex will depend entirely on fertilization or parthenogenesis. A fertilized egg will result in females and an unfertilized ovum in males. Patterson has occasionally got one or a few males in a

female brood, but these he explains on the basis of an imperfect mitosis, resulting probably in the loss of a specific chromosome which probably bore the sex-determining genes. This supposition is based on direct cytological observation. The facts of polyembryony offer a strong substantiation to the idea of chromosomal determination of sex.

### 5. SEX-LINKED INHERITANCE

The association of Mendelian characteristics with particular chromosomes is nowhere better shown than in the group of the sex-linked characteristics. The genes for these characteristics, of which alone thirty odd are known for *Drosophila*, are undoubtedly located in the sex chromosomes, and their inheritance follows the distribution of these chromosomes exactly.

Let us take for example the inheritance of red eye in *Drosophila*, a dominant sex-linked characteristic (see fig. 4). If a red eyed female is mated to a white eyed male, the  $F^1$  are all red eyed. If the  $F^1$  are again inbred, the  $F^2$  generation are three red eyed to one white eyed, but the peculiar thing is that all the white eyed individuals are males. Thus, half the  $F^2$  males are like their grandfathers. White-eyedness is covered up when the gene for red is present, and this is the case in all the  $F^1$  females. However, the eggs of the  $F^1$  female, which eliminate the red gene in the polar body in maturation and are then fertilized with a sperm bearing a Y-chromosome, will result in white eyed offspring. Thus we can say that the males have inherited their white eyes from their mothers through the X-chromosomes which she contributed to the zygotes.

Let us now examine the cross reciprocal to that given first. As shown in figure 5, we get an entirely different result. The  $F^1$  females are red eyed like their fathers, and the males are white eyed like their mothers. In the  $F^2$  generation half the males and half the females are white eyed and the others red eyed. This result is due to the fact that the male has a mechanism (only one X-chromosome) capable of bearing the gene for red but once. This is a cross therefore of a heterozygous dominant

male (red eyed) back to a recessive female (white eyed) and gives a 1:1 ratio. The  $F^1$  females (which must have two  $\underline{X}$ -chromosomes) all received an  $\underline{X}$ -chromosome from their father and are red eyed. The  $F^1$  males all received their single  $X$ -chromosome from their mothers and are white eyed.

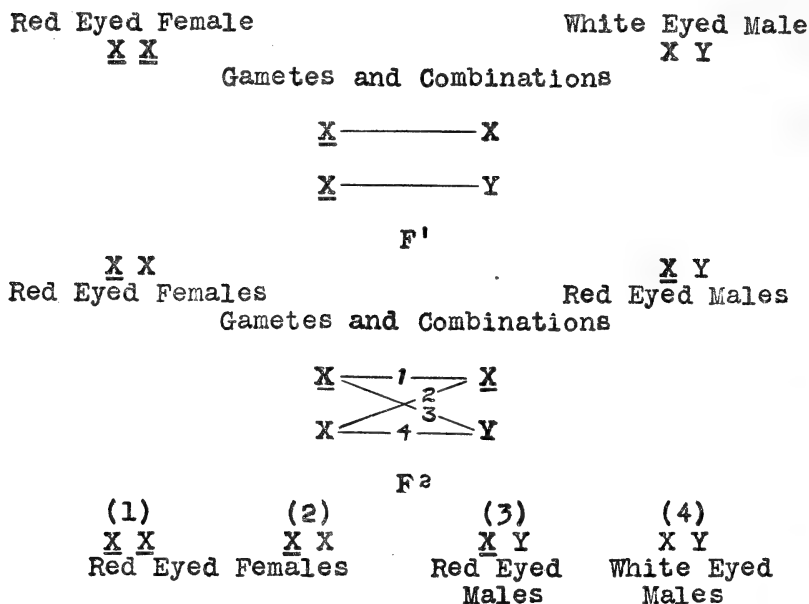


FIG. 4. DIAGRAM SHOWING SEX-LINKED INHERITANCE IN *DROSOPHILA*

An underscored  $\underline{X}$  represents an  $X$ -chromosome bearing the gene for red eye; because this is dominant over white eye, any individual with an underscored  $\underline{X}$  will have red eyes.

This criss-cross type of inheritance has long been known in man. Color-blindness is perhaps the best known illustration and behaves in its inheritance exactly like red eye in *Drosophila*. That color-blind females are so rare is due to the fact that normal color vision is dominant over color-blindness, thus  $\underline{XX}$  and  $\underline{XX}$  are females with normal color vision; but the latter is a carrier for color-blindness.  $\underline{XY}$  is a normal male and  $XY$  a color-blind male. The mating of a female carrier with a color-

blind male would result in the production of 50 per cent color-blind females as shown in the diagram, figure 6.

In animals in which the female is heterogametic (Lepidoptera and birds) sex-linked characteristics are likewise known to exist. In fact the first sex-linked characteristics were discovered in moths by Doncaster. In these cases it is the female which possesses the mechanism whereby the character in question can only be present once. Let us take, for example, barring, a

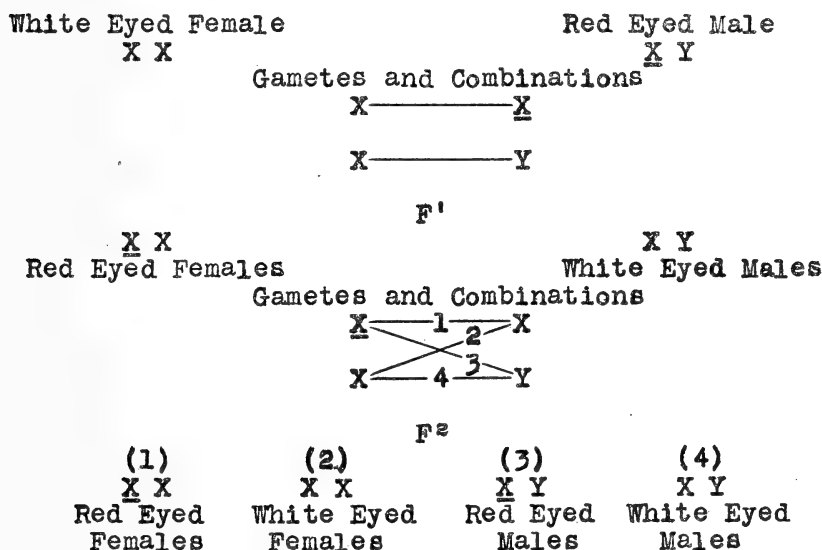


FIG. 5. DIAGRAM SHOWING CROSS RECIPROCAL TO THAT SHOWN IN FIGURE 4

dominant sex-linked trait in poultry. As shown in figure 7, the F<sup>2</sup> generation results in three barred to one black, but the black individuals are all females.

The reciprocal cross likewise shows that the character for barring follows the distribution of the Z-chromosome. As indicated in figure 8, the F<sup>1</sup> males are barred because they got a Z-chromosome from their maternal side; the F<sup>1</sup> females are black because their lone Z-chromosome came from the paternal side.



of normal males. In cattle and horses the individuals are docile compared with the fiery males. They lack the thick neck and put on fat more readily than males. In man, the voice fails to change, the epiphyses of the bones fail to fuse, the beard is weak, and the spirit dulled. Females deprived of ovaries early in life fail to develop normal mammary glands, and the skeletal characteristics likewise are much altered. Extensive experiments have proved that in birds and mammals secretions

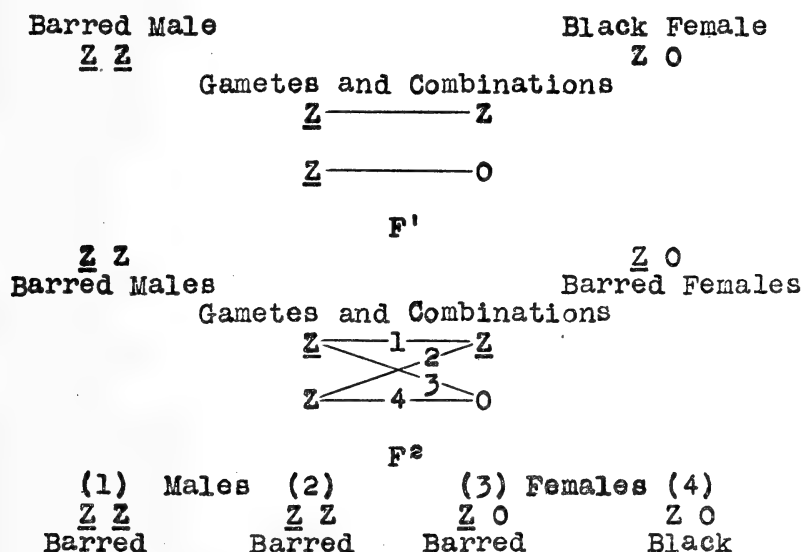


FIG. 7. DIAGRAM SHOWING SEX-LINKED INHERITANCE IN POULTRY

An underscored Z indicates the presence of the gene for barring; because this is a dominant gene, any individual with an underscored Z will be barred.

of the gonads are essential to normal development. The castration of young male rats followed by the ingrafting of ovaries causes these individuals to be feminized. They develop mammary glands, have female characteristics of skeleton and hair pattern, and also possess female sexual instincts.

Perhaps no better case of hormone influence is known than that of the freemartin, adequately explained through the observations of Lillie. He found that in cattle, when the chorionic

coverings of twin embryos of opposite sex fused so that the blood vessels anastomosed, the more rapidly developing male embryo sent out hormones into the common circulation which inhibited the normal development of the female embryo. The much modified female embryo might then be born as a freemartin. Even the ovaries show considerable alteration and tend to form tubules quite like those of a testis.

In birds the activity of the gonads likewise controls to a large extent the development of secondary sexual characteristics.

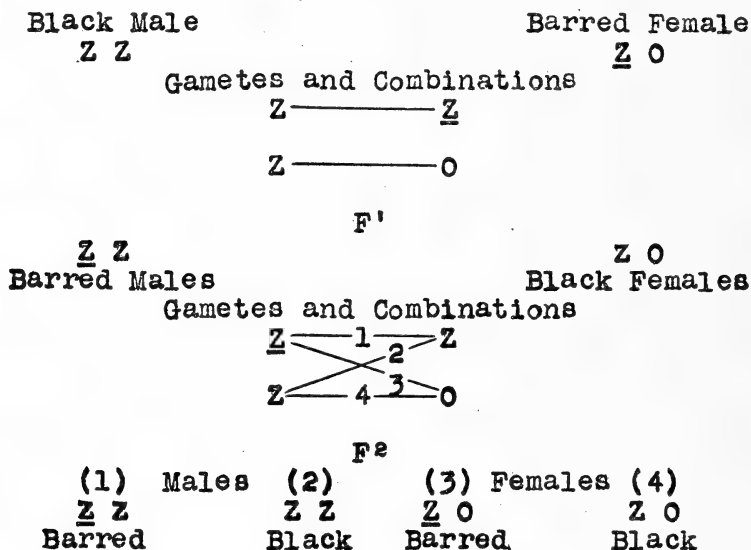


FIG. 8. DIAGRAM SHOWING CROSS RECIPROCAL TO THAT SHOWN IN FIGURE 7

This has been nicely demonstrated by Goodale and Morgan in castration and transplantation experiments on ducks and fowls. Most striking is the case of female birds, which, when castrated while still young, develop the male plumage and posture.

The whole problem of sex hormones is very complicated, for it has been shown that the secretion of the gonads is merely one link in the chain of factors, and that other endocrine glands contribute to form a complex of factors, which controls to a large extent the expression of the genes for the secondary sexual

characteristics. In the development of sex in vertebrates, the genes for the production of sex-hormones are probably second only in their importance and in their evolution to those genes which determine whether ova or sperm shall be formed in an individual.

It has been clearly demonstrated that the genes for the secondary sexual characteristics lie in the autosomes and therefore each sex has also a double set of those for the opposite sex. The expression of one set or the other will depend on the sex genes. Thus for example in cases where the male is heterogametic, the presence of a single X-chromosome in all the cells of the individual, together with the normal secretion of the male gonads, causes the male genes for the secondary sexual characteristics to develop. By castration and transplantation of ovaries into an immature individual, the normal condition may be upset, and the female secondary sex genes brought into action, as in Steinach's feminized rats.

It has been well demonstrated in insects that castration even of very young individuals produces no effect upon the secondary sexual characteristics when the animal reaches its adult form. Even the implantation of gonads of the opposite sex results in no change. The growth and development of the soma seems fixed by its chromosomal complex and not alterable by any sex-hormone. This rigidity of sexual development in insects may be coupled with the fact that normal hermaphroditism is extremely rare in this group.

Crustacea and insects, when parasitized, may show alterations of the secondary sexual characteristics, especially in the case of the males which then appear externally like females. In the Crustacea the best case is perhaps that of *Inachus*, described by Smith. The parasitized male becomes similar to the normal female in the form of its claw, abdomen, and abdominal appendages. Among insects *Thelia bimaculata*, described by the author, is a most striking example. Parasitized males resemble females even to the minute structure of the chitinous integument. Such alterations are most likely due to an entire upset of the metabolism of the host and the internal environment is such

that the genes for the male secondary sexual characteristics fail to find the necessary conditions for their expression in the developing soma.

#### 7. GYNANDROMORPHS AND MOSAICS

In insects and crustacea there occasionally appear abnormal individuals which are mixtures of male and female individuals. Sometimes the demarcation is exactly median, one half being male, and the other half female. These are true gynandromorphs. There are, however, cases where the division is dorso-ventral or antero-posterior, and again the individual may be a "patch-quilt" of male and female parts, these latter being mosaics or intersex individuals such as described for moths by Goldschmidt and for daphnids by Banta.

Insect gynandromorphs do not necessarily have the gonad of the corresponding sex in their respective halves, showing that the soma is not moulded by sex hormones. The cause of gynandromorphism was studied by Boveri and also by Morgan. Boveri claimed for gynandromorph bees of crossed races that the male half was maternal, and the female half hybrid. If after the division of the egg nucleus a sperm united with one of the two daughter nuclei, that half would be female, whereas the sister nucleus developing parthenogenetically would form a male half which would be purely maternal. This explanation holds good for some cases, but Morgan finds in *Drosophila* that the male portions often bear paternal characteristics due to genes lying in chromosomes other than the X-chromosome. He, therefore, concludes that at times an X-chromosome is lost in the mitosis of a (female) zygote, and the nucleus which fails to get two X-chromosomes develops into the male portion of the gynandromorph. A misplaced X-chromosome in a primary germ cell may cause testes to form in a female. Such a case was found in *Thekia* where an actual chromosome count proved an X-chromosome to be missing in all the countable metaphase plates. The soma of the individual was purely female, however.

It is rather difficult to offer any simple mechanical explanation for the mosaics or sex intergrades of moths and daphnids. Gold-

schmidt has attempted to explain his results upon a quantitative basis, assigning values for the determiners for maleness and femaleness together with the postulation that the strength of these determiners varies in different races. Thus, the crossing of a strong male race with weak male races brings about an upset of the normal conditions and establishes a balance of factors where neither one sex nor the other predominates, and thus we get the expression of two sets of genes in various parts of the organism. Bridges' recent work on intersex forms in triploid races of *Drosophila* would indicate that where the normal relation of sex genes (located in the X-chromosome) to the autosomal genes is upset, either by a preponderance of one or the other, then sex abnormalities of many sorts may be expected.

#### 8. HERMAPHRODITISM

One of the most obscure problems of the entire sex question is that of hermaphroditism, the production of ova and sperm by a single individual. This condition is found normally in many groups of invertebrates: coelenterates, ctenophores, flat worms, round worms, annelids, molluscs, and some crustacea. It is, however, the exception rather than the rule and must be viewed as a modification of the bisexual condition necessitated to insure insemination in animals of a less gregarious nature. Sometimes hermaphrodites are female in form, and again they resemble more closely males of the group to which they belong. In certain nematodes, as in *Rhabdites aberrans*, an occasional male is found among thousands of hermaphrodites of female form. Miss Krüger has shown that occasionally there is the failure of one chromosome to become incorporated in one of the second spermatocytes. Spermatozoa resulting from such deficient spermatocytes may be the cause of those occasional zygotes which result in males. Boveri and Schleip have shown that in the case of *Angiostomum*, a nematode in which hermaphroditic individuals give rise to a sexual generation, male-determining sperm are formed through the failure of one-half of the spermatids to include the X-chromosome. Since our knowledge of the chromo-

somes in hermaphroditism is scant, it is hardly worth while at present to speculate on the mechanism which produces such individuals.

That the sexual tendencies of hermaphroditic forms is often in a sensitive balance, influenced by external conditions, is shown by the experiments of Baltzer on *Bonellia* and Gould on *Crepidula*. In *Bonellia* there are produced minute motile larvae with hermaphroditic potentialities. If the free swimming larvae find the proboscis of a female *Bonellia*, they attach themselves and develop into minute males after a parasitic existence of about four days. If, however, no proboscis is found, the motile larva sinks to the bottom and develops into a female. In this case we may say that probably some secretion from the proboscis of the female stimulates the development of the male anlage and that this is accompanied by the suppression of the female fundamentals. Likewise the absence of the proboscis secretion allows the female fundamentals to develop while those of the male are suppressed. Intermediates were produced by Baltzer by allowing larvae to attach to a proboscis and then removing them at intervals of less than four days. In *Crepidula plana*, a hermaphroditic gasteropod which is normally a protandric hermaphrodite, Gould has shown that the presence of older individuals in the female state of development causes the production of sperm in small individuals nearby. Isolated small individuals, however, omit sperm production and form ova. Here is an animal in sensitive balance influenced by a secretion which probably comes to it through the sea water. The problem of hermaphroditism, its mechanism and relationship to bisexual reproduction, is well worthy of intensive study. From such exceptions to the general rule we may hope to learn much about the normal mechanism of sex-determination.

## 9. CONCLUSION

Finally, one may ask can sex ever be controlled? There seem to be two avenues of approach. In forms in which the female is heterogametic, external conditions may control maturation

and thereby sex, as in the case of Seiler's moths and Riddle's pigeons. Where, however, the male is heterogametic, sex could be controlled only by an agency which would differentially aid or inhibit the progress of one of the two types of sperm in its approach to or penetration of the ovum. The way is not closed and the facts so far learned about sex-determination make it seem not at all unlikely that definite control of sex will be established for many organisms in years not far distant.

## THE MEANDER PATTERNS OF RIOS SECURÉ AND MAMORÉ, EASTERN BOLIVIA<sup>1</sup>

KIRTLEY F. MATHER

The greater part of northeastern Bolivia is a lowland plain drained by a network of streams which unite to form Rio Madeira, one of the larger tributaries to the Amazon. Between Guajara Mirim and Porto Velho (see fig. 1), the Madeira crosses the northwestern extremity of the Pre-Cambrian shield of Brazil<sup>2</sup> in a series of cataracts and rapids. The altitude of the river bed at the first of the cascades, close to Guajara Mirim, determines the level of the floor of the entire basin stretching from that point to the eastern foot of the Andes of Bolivia and Peru. The streams from the mountains debouch upon this lowland, heavily laden with silt, and the plain is in consequence a plain of aggradation. Its surface is between 600 and 1000 feet above sea level, and slopes with remarkable uniformity and exceedingly low gradient from the foot hills of the Andes to the head of the cataracts of the Madeira. Because of the uniformly low gradient the streams which traverse this featureless plain for hundreds of miles have developed meanders of unusual complexity and perfection. The opportunity which they afford for the study of old age stream patterns is excellent.

While engaged in geological explorations for Richmond Levering and Company in August and September, 1920, I crossed the eastern Andes from Cochabamba to the headwaters of Rio Chaparé, and travelled overland in the foothill region to Rio Securé.<sup>3</sup> After a brief examination of the upper reaches of this

<sup>1</sup> A paper presented before the Section of Geology of the Ohio Academy of Science, April, 1922.

<sup>2</sup> Branner, J. C., Geol. Map of Brazil, Bull. Geol. Soc. of Amer., vol. 30, plate 7, 1919.

<sup>3</sup> Mather, K. F., Explorations in the Land of the Yuracarés, Eastern Bolivia; Geographical Review, vol. 12, pp. 42-56, 1922.

river, I travelled as rapidly as possible to Trinidad, descending Rio Securé and Rio Mamoré. The journey gave me an oppor-

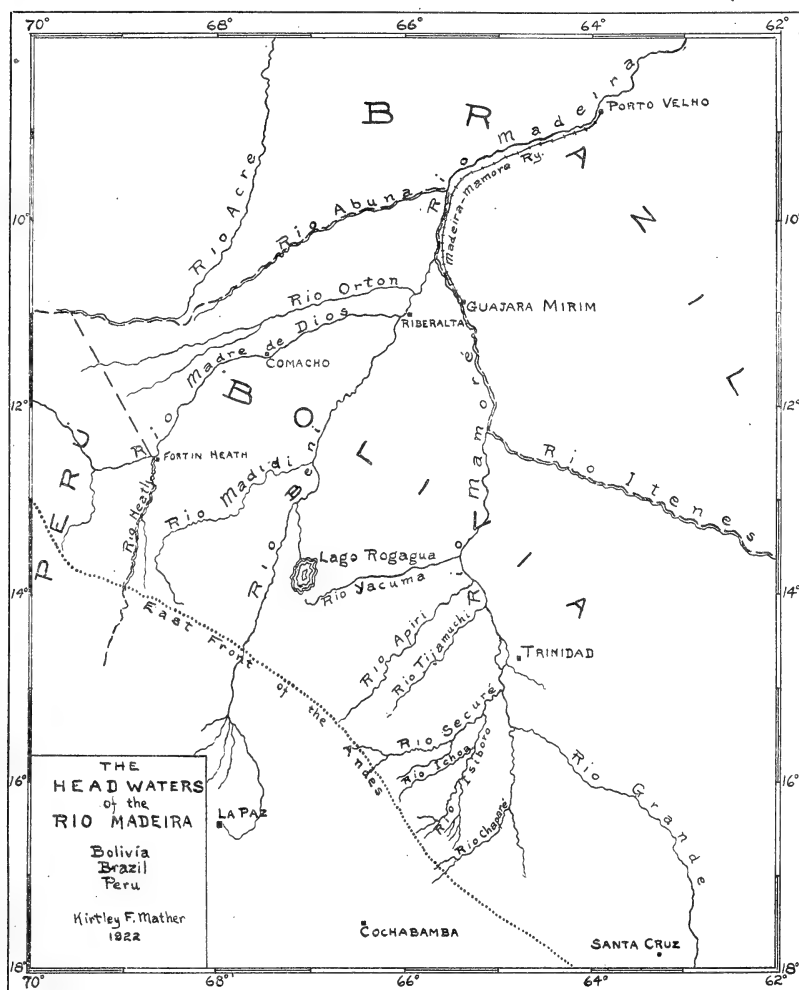


FIG. 1

tunity to map portions of the rivers and provided the data for this paper.

The exigencies of travel made the compilation of the map of secondary importance, and therefore the methods used in map-

ping were perforce such as would not delay progress. Transportation was by means of dugout canoes, propelled and piloted by Yuracarés Indians. Directions were determined by frequent readings of a Brunton compass; distances were approximated by noting the interval of time which elapsed while the canoe was on the determined bearing. The speed of the canoe had been previously ascertained by timing it over a marked course, and, although the methods used in making the map were obviously crude and subject to considerable error, it is believed that the results obtained in the main are fairly accurate.

Rio Securé, above the junction with Rio Isiboro at Puerto Calvimonte, averages a hundred yards in width. It is a brown, silt laden stream, sliding swiftly between banks of clay or sand, capped with six or eight feet of rich black soil, which rise abruptly from the water's edge to the level of the jungle covered plain. At low water these banks are 15 to 25 feet high, but in the rainy season the river brims its banks and floods the ground between the trees of the tropical jungle. The Isiboro is nearly as large as the Securé above the junction of the two. The Securé's volume is therefore nearly doubled at Puerto Calvimonte. From that point to its mouth the river averages a little over 150 yards in width. Rio Mamoré is a much larger stream, with a width of at least a quarter of a mile at low water, between the mouth of the Securé and the vicinity of Trinidad. A detailed map of the lower part of the Securé and a portion of the Mamoré forms figure 2. Throughout the area of this map and for many miles upstream and downstream beyond it, the gradient of the Securé and Mamoré is practically constant, less than half a foot per mile of river course.

The meander patterns of the rivers, shown in figure 2, are characteristic; curve follows curve in dizzy succession along the tortuous stream course. The typical meander curve is not an arc of a circle, but is formed of short sharp bends alternating with long, comparatively straight stretches. Many times while paddling steadily downstream we found ourselves within a hundred yards or so of the place where we had been an hour before. Occasionally we noted cut-offs where during the previous rainy

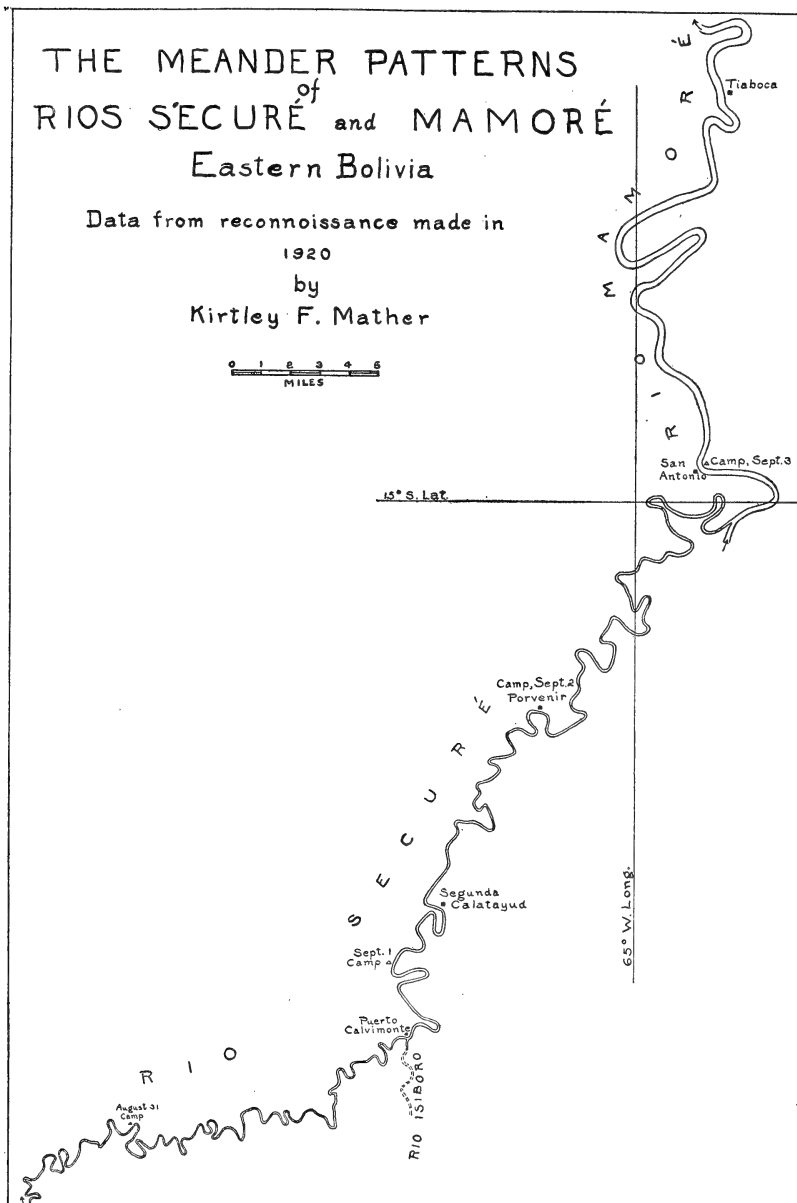


FIG. 2

season the stream had straightened its course and abandoned a long-used channel; elsewhere the river banks were reduced to a knife-edge by the close crowding of meander loops.

Apparently there is a definite correlation between the meander pattern and the volume of the stream; this conclusion is really the excuse for this brief note. Where the river volume is comparatively small, meander curves are numerous, close-crowded, and short. With increase in volume the curves become longer, more widely spaced, and fewer. Three distinctive patterns are clearly shown in figure 2. These correspond to the varied volume of the streams involved. The Securé above its junction with the Isiboro displays twice as many meander curves in a given distance as are found below Puerto Calvimonte, where its volume is nearly doubled by the accession of the Isiboro. Likewise the lower part of the Securé has many more meanders than has the Mamoré, much the larger of the two streams.

This change in meander pattern seems to be solely a response to the change in volume of the rivers. The gradient is not altered, nor is the current appreciably swifter. The change, as indicated by the map, involves a lengthening of the straight stretches between the short sharp curves. Possibly the greater inertia incident upon the larger volume is the major cause of the modification.

It is of interest to note that in this land, where transportation routes and lines of travel are restricted to the navigable waters, the untutored Indians are sufficiently adept physiographers to note this correlation between river volume and meander dimensions. Distances between *chacras*, the tiny clearings under cultivation along the river banks, are reported in terms of the numbers of "turns" in the river's course. Thus I was told that it would be five "turns" from the mouth of the Securé to the port of Trinidad; but that because the Mamoré was very wide the "turns" were very long, and it would require from sunrise to sunset to traverse the distance.

A little later in the same field season I had opportunity to check the conclusion, reached on the Securé and Mamoré, by similar observations on Rio Heath and its tributary, Rio Najegua,

on the frontier between northern Bolivia and eastern Peru (fig. 1). The Najegua is less than a third as large as the Securé, but its gradient is approximately the same. In harmony with its slight volume, its meander curves were very short, extremely close spaced, and numerous. Working upstream in it, at a pace of  $2\frac{1}{2}$  miles per hour, it was necessary to take bearings every minute or two in order to get any results at all from the effort to map its tortuous course. Rio Heath, only slightly less in volume than the Securé, has a meander pattern practically identical with that of the Securé above Puerto Calvimonte.

## PRIMITIVE MUSICAL INSTRUMENTS OF THE DENISON COLLECTION

KARL H. ESCHMAN

The collection of primitive musical instruments at present located in the building of the Conservatory of Music, Denison University, although small in number, includes all the main types of instrumental evolution. It is the result of miscellaneous gifts of alumni from mission fields. The fact that this collection so completely illustrates a brief outline of the subject, it is thought, should encourage other colleges with departments of music, to begin collections of like character.<sup>1</sup> In addition, it is hoped that a description of some of the specimens may be of interest to students of the subject.

With the aid of certain ethnological principles, and by methods not unlike those used in the classification by distribution, of fossil remains in strata of different periods, an order of evolution of musical instruments has been formulated, which may be accepted in general. In determining the priority of instrumental types, we are hindered by the nature of the materials themselves. However, by collecting instruments from tribes which represent all stages of civilization existing at present, we can secure, of course, illustrations of many periods of construction. It is this fact which adds to the interest of any collection, whatever the age of the particular instruments themselves. There have been two opposing theories of priority: one starting with the percussion type, and the other favoring the pipe or horn type. Both types are so simple as to need little ingenuity for construction. Handclapping would easily lead to the beating of objects together, and shouting through the hands would be followed by

<sup>1</sup> The splendid collections at the University of Michigan, Yale, and Pennsylvania, as well as that at the Metropolitan Museum, New York, are based upon the gift of a single large private collection.

the use of a crudely rolled horn, while natural whistles literally grow on bushes wherever reeds and bamboo are found.

The weight of authority, however, is with the former theory, as is also the evidence of ethnology. In fact, all seems to point to the following arrangement, which also coincides with relative difficulty of manufacture and complexity of idea:<sup>2</sup>

- I. Indefinite percussion
- II. Wind instruments—pipe type
- III. Wind instruments—horn type
- IV. Definite percussion
- V. Stringed instruments—without fingerboard
- VI. Stringed instruments—with fingerboard
- VII. Stringed instruments—with bow, without and with fingerboard
- VIII. Multipipes—organ type.

#### I. INDEFINITE PERCUSSION

1. Ngoma (war drum)—*Africa*. This most primitive type of drum is a section cut from a tree-trunk. Hollow trees are still occasionally used as drums, and the attempt to make such stationary instruments portable, probably produced the first drum of this character. This drum is 96.8 cm. in length by 34 cm. in diameter at the largest end. The body is cut down by a sudden shoulder to a diameter of 12.5 cm. at the smaller end. The drum is crudely hollowed out, and this small end has an opening 8 cm. in diameter, surrounded by a tin collar but with no leather head. This narrowing, and the small opening, even without a head, greatly aids the sonority. The rawhide head at the larger end is fastened to the drum by three rows of wooden pegs. Two sets of three wooden projections and one of two, were left on the drum when carved, to be used as handles or for thongs.

2. Ndunga—*Africa*. This drum is 304 cm. (9 feet 8 inches) in length, and is interesting as one of the few drums of this type in American collections. Drums of still larger size are made by the natives. This tree-trunk has been trimmed with greater care than the Ngoma above, to 26.5 cm. diameter at the large end and 12 cm. at the smaller. Both ends are covered with hide and are strung together by ten thongs of rawhide with hair

<sup>2</sup> This outline has been simplified for use with illustrations selected.

attached, running the entire length of the drum. It is carried by four men, two on each side of a long handle which is carved from the body of the tree. The drum as well as the drum-stock (32 cm. long, 2 cm. diameter) which is not padded, is painted in alternate red and black circles.

3. Drum—*Africa*. A well made cylinder, 49.5 cm. in length, 26 cm. in diameter, has two heads laced together by a very intricate network of rattan which covers the entire drum. The whole drum evidences much more skill of workmanship than the preceding, and produces a very satisfactory tone, as the tight lacing greatly increases the resonance.

4. Ozee (stationary drum)—*Burma*. This drum is made of wood in the shape of a goblet 38 cm. high and 15.5 cm. in diameter, lacquered black and red. The head is painted with a smaller circle of black and is fastened by thongs to a wire at the base of the head. The wooden base of this drum is hollow. A companion drum of the same general size and finish has a skin on each end and a thong which slips around the neck, making it possible to play with the fists while moving about.

## II. WIND INSTRUMENTS—PIPE TYPE

5. Siakuhachi—*Japan*. This direct flute is made from a thick bamboo stem, using the natural swell of the reed. It is blown at one end where a piece is cut off to afford a position for the lip. The length is 49 cm. and the diameter 1.7 cm. swelling to 2.3 cm. There are four finger-holes in the front and one in the back, while other smaller subdivisions of pitch are obtained by only partly closing these holes with the fingers. There is a distinct pattern for this type so that the distance from joint to joint of the bamboo averages 17, 14 and 8.5 cm. respectively. This specimen measures 18, 14 and 9 cm.

6. Traverse flute—*Burma*. This flute is lacquered black and has a ring of ivory at each end; 40.5 cm. long, 2 cm. diameter. Six holes for fingering and one for blowing.

7. Ti or Yuëh—*China*. Seven holes in front and one in back of pipe. The mouth-hole is divided by a small partition into two parts. Made of bamboo, 28 cm. long, 1.5 cm. diameter.

8. Fife—*Garó*. Traverse; very small bore; reed 55 cm. long, 1.1 cm. inside diameter. The finger holes are near the opposite end from the mouth-hole.

### III. WIND INSTRUMENTS—HORN TYPE

9. Wooden trumpet—*Africa*. Total length, 87 cm. In this horn the mouthpiece is on the side, and the actual blowing length is 58 cm. The diameter at the large end is 9 cm. From the mouthpiece to the open end, the horn is covered with natural fibre and wrapped with rattan.

### IV. DEFINITE PERCUSSION

10. Gong—*Burma*. Diameter 18 cm. with a 3 cm. edge turned up; but slight attempt at decoration.

11. Kyizi—*Burma*. Two very small hollow hemispheres of bronze through which a string is fastened, are allowed to strike together, giving the impression of tinkling bells. These are only 3 cm. across.

12. Zanze or Biti—*Africa*. Eleven tongues of iron are mounted on a hollow sound board in such fashion that they can be plucked by the thumbs when the instrument is held in the two hands. This instrument is akin to the marimbas but scarcely a typical percussion type. According to the savage notion, the twanging is made more beautiful by the rattling of small beads on some of the tongues, when the instrument is played. The box is 27.5 cm. by 13 and 16 cm. (flaring) and 1.5 to 3.5 cm. deep. The vibration of the other end of each tongue is stopped by a strip of leather on the face of the instrument. The scales of no two instruments of this type are alike. The Denison specimen gives: g' flat, f', c', a', B, A flat, A, d flat, f, b, e'.

### V. STRINGED INSTRUMENTS—WITHOUT FINGERBOARD

13. Gopi-Jantra, Monochord—*Garó*. (Tura, Assam.) A calabash gourd is fitted with a skin bottom through which a single wire is fastened by means of a button. (This use of a European

button is thought highly ornamental.) A piece of bamboo is split part way and fastened to the sides of the gourd, and to this, the wire is stretched by means of a single peg in the side. Total height 78 cm.; diameter of body, 18 cm.; very primitive. The pitch is changed by pressing in on the bamboo strips while the tone is sounded.

14. Ichigenkin or Sumagota (monochord)—*Japan*. The one string is stretched over a board of cherry-wood 110 cm. long and 10.5 cm. wide. The supporting ivory bridge is missing in this specimen. The string is tuned to f $\sharp$  of our scale—a note which may be considered the principal note of the Japanese tonal-system. All Japanese instruments are elaborately decorated. This one has a circular piece of embroidery near the end, and is suspended by a red and yellow cord from the other end when not in use. When played, it is laid horizontal on a low table. The instrument has no fingerboard, but the pitch is changed by an ivory cylinder worn on the second finger of the left hand which is pressed against the string to furnish nodes for the different notes. The ivory spots or designs found on some instruments to indicate these points, are not present in this specimen.

#### VI. STRINGED INSTRUMENTS WITH FINGERBOARDS

Samisen—*Japan*. This instrument has a fingerboard but no frets. It is related to the Chinese Sanheen, each having three strings and a long neck. The body of the Sanheen is round and of the Samisen rectangular, in this case 20 cm. by 18 cm., 10.5 cm. thick, covered with catskin. The length of the entire instrument is 94 cm. The three strings are turned in three ways:—c' $\sharp$ , f' $\sharp$ , c'' $\sharp$ , c' $\sharp$ , g' $\sharp$ , c'' $\sharp$ ; and g' $\sharp$ , c'' $\sharp$ , f'' $\sharp$ . The Samisen is played with a large wooded pick over 20 cm. long, the strings being struck below where the neck joins the body. The face is strengthened there with a small extra piece of parchment which receives the blow of the pick, thus producing two sounds, the plucking of the strings and the stroke on the body.

16. Yueh Ch'in (Moon guitar)—*China*. This instrument derives its name from its round shape, 33.5 cm. in diameter, and 3.5 cm. thick, both surfaces being flat. It is the first string

instrument on our list which gives in its construction, information as to actual scale relationships. There are eleven very high wooden frets, eight on the body and three on the neck. The top one serves as a bridge and the frets decrease in height all the way down. The four strings are tuned in pairs, and are often plucked with the finger nails which are grown conveniently long. A loose wire fastened inside the body jangles when the instrument is played, and adds to the effect, somewhat as the beads do in the African zanze.

17. Gekkin (Moon guitar)—*Japan*. A comparison with no. 16 shows the intimate connection between China and Japan. The Japanese instruments always show much more care in construction and beauty of ornament than the parallel type in China. The sizes of the two instruments are almost identical (the body of the Gekkin is 34 cm. diameter, by 3.5 cm.) but the number and locations of the frets are different. The Gekkin has nine in all, four on the body and five on the neck. The frets are of ivory. Carved wooden ornaments are located about where sound-holes might be expected on a medieval viol. A snake skin protects the face of the instrument from the blows of the small pick. This instrument also contains a snare.

#### VII. STRINGED INSTRUMENTS WITH BOW .

18. Mendicant's fiddle—*Thibet* (Darjiling). This instrument is a crude Thibetan counterpart of the Chinese urheen (19) and in every way shows its low origin. There is only the slightest attempt at decoration with inaccurate cross-markings on the neck. The tuning-pegs are not mates, but evidently have been picked up somewhere, and put to this use. The two "strings" are simple bunches of about a dozen horse-hairs each, like those on the bow. The evolution of bows is in itself an interesting subject. This bow is most primitive, being simply a bent stick, but there is a notch at one end which makes it possible to loosen the hair when not in use. A peculiar feature of this instrument (as of no. 19) is that the hair of the bow passes between the strings so that the bow cannot be removed from the strings. The body of the instrument, which corresponds in position to the

head of a mallet, is a section of bamboo 10 cm. in diameter and 13 cm. long. The skin head is fastened on with wooden pegs which project irregularly.

19. Urheen—*China*. This type is one of the oldest Chinese stringed instruments. Although this specimen shows great care in construction, having inlaid pegs and top, it is almost as primitive as no. 18, because the hair of the bow passes between the strings; and, as the strings are too far from the neck to be stopped, only one combination of tone is possible. The improvement over no. 18 is mainly in the strings themselves, which can be tuned to f ♯ and c ♯. The rasping sound of this open fifth is the only musical effect of this instrument. The bow is an advance, having something of the contour of a modern violin bow, but it does not seem to have been given the care bestowed on the instrument itself. The cylindrical body 11.5 cm. long by 8 cm. diameter, is made of wood covered with a snake-skin head.

20. Fiddle—*Tibet*. The body of this fiddle is made from a cocoanut shell, with a skin head fastened down over half the surface of the shell. A bundle of horse-hairs is stretched from the head to a peg in the handle. The wooden bridge is not fixed to the face of the head but is tied to the neck of the instrument by a string, and placed in position only when the hair is tightened. The hair of the bow does not pass between the hair of the string in this case. An interesting feature of this instrument is the fact that the maker has used part of an old flute for the neck, placing the mouth hole near the head and leaving four finger holes at the other end, into one of which the peg is placed. This use of old material at hand is characteristic although unexpected. Personal and tribal traits of this sort add interest to any collection of primitive instruments.

#### VIII. MULTIPIPES—ORGAN TYPE

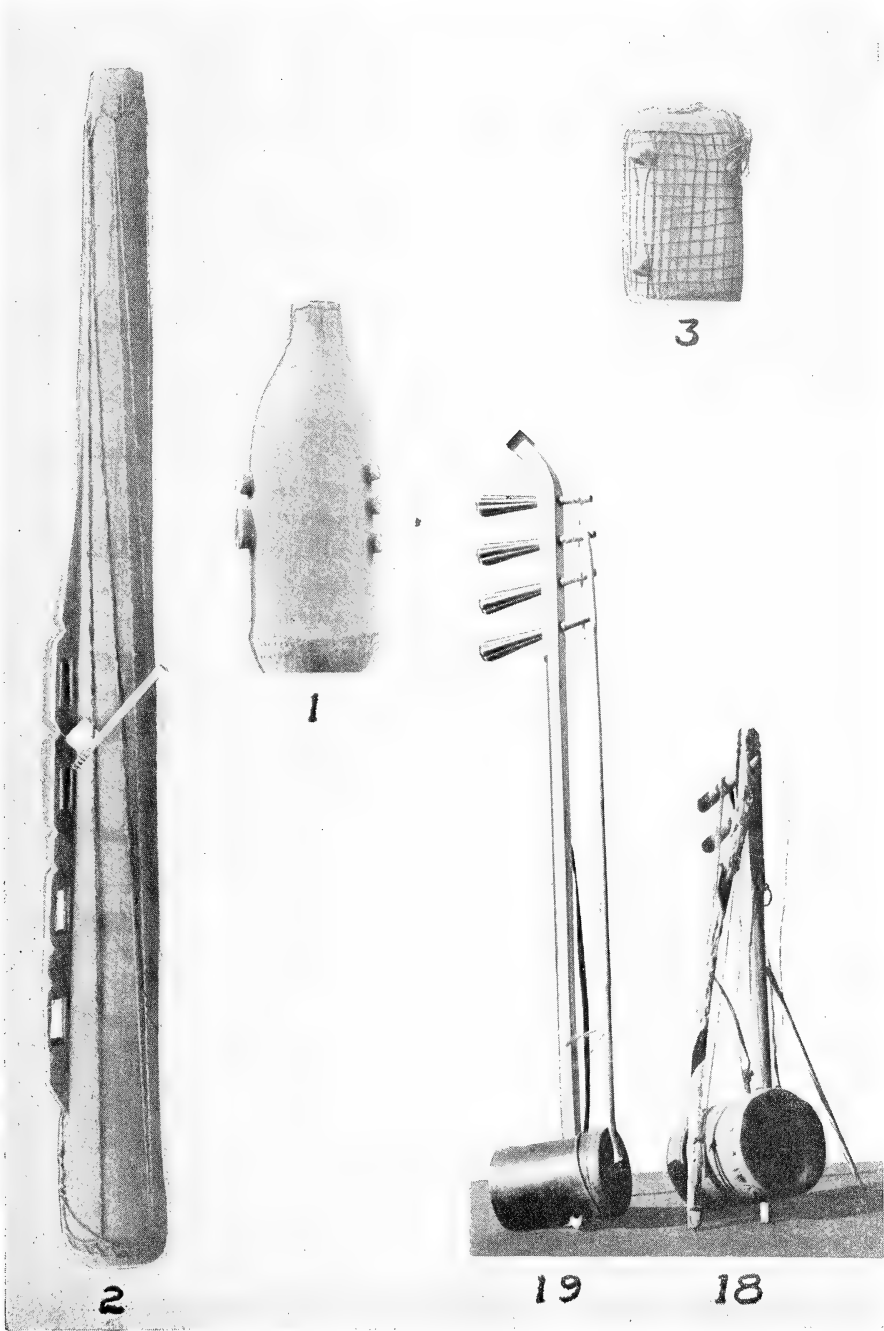
21. Muhso flute.—*Burma*. A reservoir made from a calabash gourd has five open pipes. The open pipes make possible a second tone from each pipe, by closing the lower holes which open on the bottom of the gourd. Because of the difficulty of

holding more than two pipes in the mouth, a substitute reservoir was sought. In some sections a hollow lump of clay is used, into which the pipes are fastened. No. 22 shows a further advance.

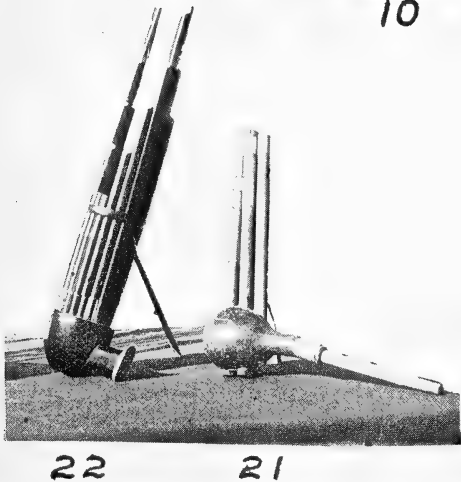
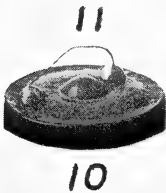
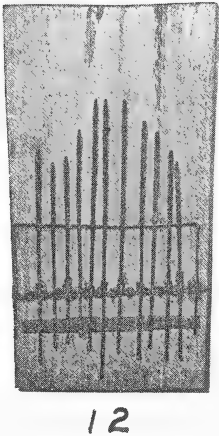
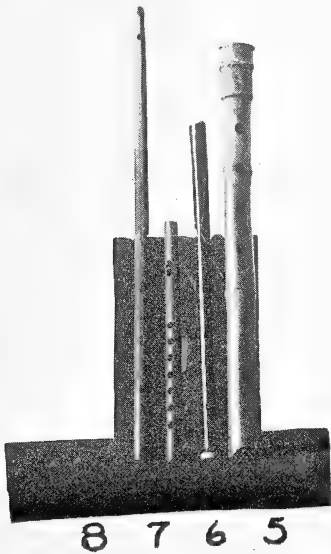
22. Sheng—*China*. Seventeen reeds of small bore are set in a lacquered cup of cherry-wood. The mouthpiece in primitive instruments was a long spout like that of the Muhso flute above, but it is now a much shorter projection covered with an ivory plate. Each of the pipes contains a very small free reed of copper, set level with the frame. The instrument is played by inspiration—i.e., by drawing in the breath—as otherwise moisture might settle on the reeds and affect the pitch. There are many interesting features connected with this instrument—the use of two mute pipes and the curious arrangement of pipes which gives it the Chinese name of “Bird-on-the-nest,” the fact that sounding length of the pipes is different from the apparent length, and the use of a free reed at such an early date. (The type is thought to be at least three thousand years old.)

From the standpoint of the theory of scales there is the question of a mechanical origin of the sheng scale procured by the successive halving of differences, starting with the longest pipe, which is just the length of the Chinese foot. Further, the duplication of two notes of f ♯ and g ♯ by the use of four pipes, suggests an attempt at equal temperament—i.e., the production of true fourths with the upper and lower c sharps. The only difference in the scale of the Denison sheng from the normal type is that pipe no. 7 (counting from the left of the opening) gives c'' and pipe no. 11 gives c,''' while in the usual instrument these are reversed.

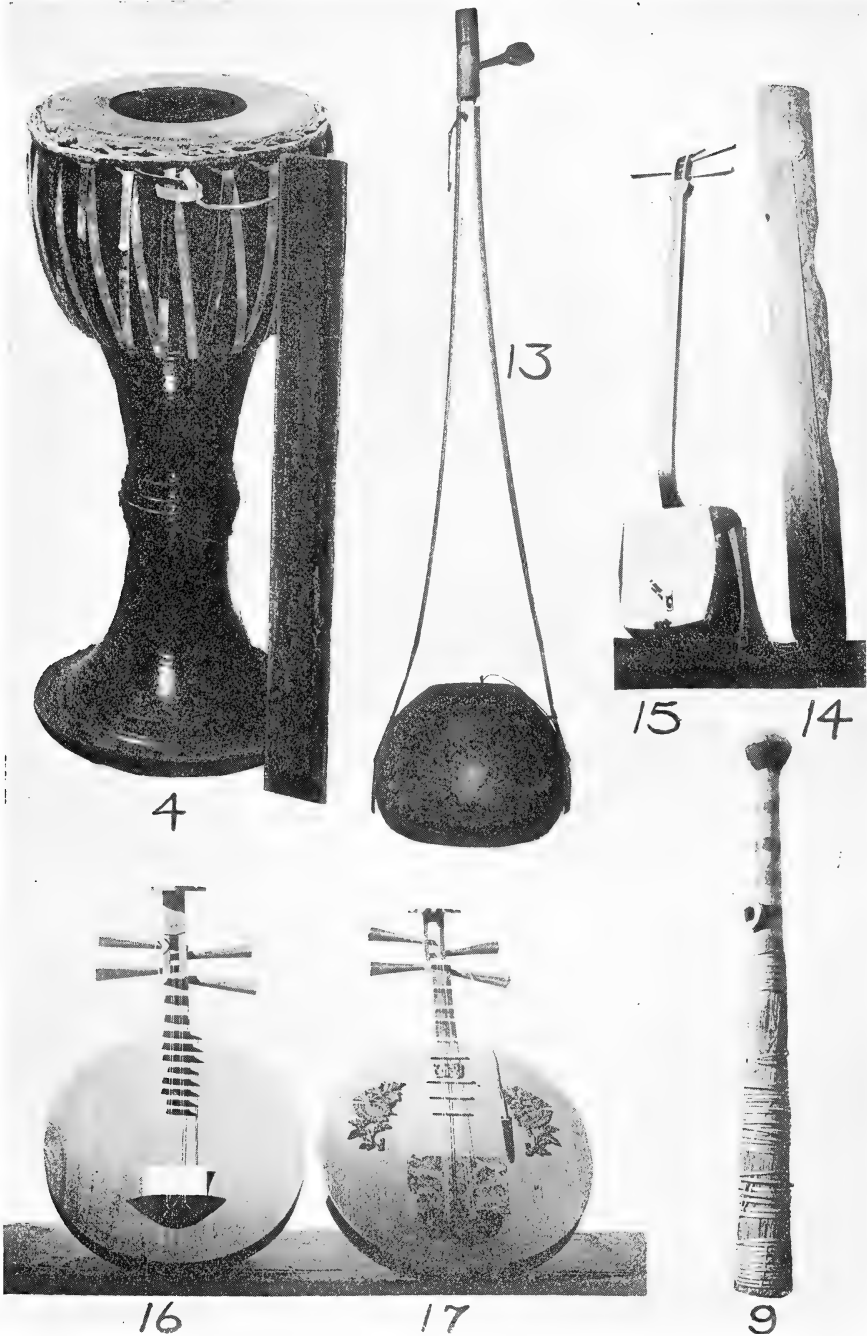














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# DENISON UNIVERSITY BULLETIN

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## JOURNAL OF THE SCIENTIFIC LABORATORIES

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Articles 4-8

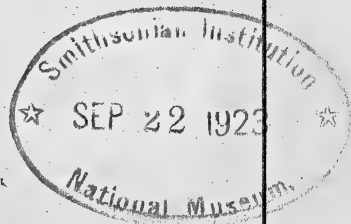
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## OF

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Edited by

KIRTLEY F. MATHER

Permanent Secretary, Denison Scientific Association,  
Granville, Ohio

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 Bulletin in commemoration of Clarence Luther Herrick.

# NOTES ON MEDINAN, NIAGARAN, AND CHESTER FOSSILS

AUG. F. FOERSTE

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## A. THE CORRELATION OF OHIO, INDIANA, AND KENTUCKY MEDINAN AND NIAGARAN STRATA

In East-Central Kentucky the following Silurian strata, in descending order, may be discriminated.<sup>1</sup>

Crab Orchard division of Niagaran	{	Alger formation	{ Estill clay Waco limestone Lulbegrund clay
		Indian fields formation.	{ Oldham limestone Plum creek clay

Medinan                      Brassfield formation    Brassfield limestone

The so-called Waco limestone is merely that part of the Alger formation in which a few limestone layers occur. In the type area one of the limestone layers is from 1 to 2 feet thick. The other limestone layers are less than 1 inch thick. Fossils occur both in the limestone and in the clay shale. Neither limestone nor fossils can be traced north of Indian Fields, Kentucky, and

<sup>1</sup> Foerste, A. F., The Silurian, Devonian and Irvine formations of east-central Kentucky: Kentucky Geol. Survey, Bull. 7, 1906, p. 27.

farther north the collective term Alger clay is used for the continuous clay shale section forming the upper part of the Silurian in Montgomery, Bath, and most of Fleming county. In Lewis county, and in the northern part of Fleming county, this Alger clay is overlain by the Bisher member of the Niagaran. In Lewis county the upper part of the Alger clay contains *Liocalymene clintoni* and other fossils indicating relationship with the Clinton of Maryland and the typical Clinton of central New York, as exposed in the vicinity of the village of Clinton in that state.

The Oldham limestone consists of thin limestone interbedded with thin clay shale. It contains very few fossils and of these only *Stricklandinia norwoodi* has been recorded. Since this species does not occur elsewhere than in east-central Kentucky it is of no service in correlation. The Oldham limestone may be followed lithologically as far north as the Rose Run Quarries, about 7 miles east of Owingsville. Farther north it can not be discriminated readily from the underlying Plum Creek clay shale, since the latter there also contains thin limestone layers, often in considerable quantity.

Throughout southwestern Ohio there is a series of very white and fine grained limestones known as the Dayton limestone. In Highland and Adams counties in Ohio, and in the adjacent parts of Lewis county in Kentucky, this Dayton limestone lies immediately beneath a thick clay shale zone regarded as the northward extension of the Alger clay. Since the Dayton limestone in Highland and Adams counties contains *Pentamerus oblongus*, it is regarded provisionally as corresponding to one of the so-called Clinton *Pentamerus* horizons of the more western parts of New York. Possibly it corresponds approximately to the Walcott limestone of the Clinton as exposed in the Rochester area of New York. In that case the Dayton limestone forms the base of that part of the Ohio Niagaran which corresponds to the Clinton of New York, when this term is used so as to include the Clinton of Western New York at Rochester and as far west as Niagara Falls and southern Ontario as well as the typical area around Clinton, New York.

Nothing is known of the fossils of the Plum Creek clay shale, at least within the area of its typical exposure. Farther north, at the Rose Run quarries, east of Owingsville, Kentucky, a considerable fauna once was exposed in strata overlying the iron ore horizon. This fauna never was collected but it contained species resembling *Clathropora clintonensis*, *Strophonella daytonensis*, and other species resembling forms known in the Brassfield limestone, but at the time this fauna was examined in the field it was regarded as sufficiently distinct from the typical Brassfield to be regarded as probably of Niagaran age.

The Brassfield limestone is regarded as equivalent to part of the Medinan section in the Niagara Falls area of New York and in southern Ontario.

At the base of the Brassfield limestone, in the quarry immediately north of Lawshe, in Adams county, Ohio, *Platymerella manniensis* Foerste was found in a thin horizon only a few inches thick.<sup>2</sup> This occurrence is of interest because the same species occurs at a corresponding horizon in western Illinois and eastern Missouri.<sup>3</sup> At these western localities the *Platymerella* horizon is underlain, in descending order, by the Essex, Edgewood, and Girardeau limestones. Recently fossils have been found in argillaceous strata underlying the typical Brassfield limestone, in Montgomery county, Ohio. These beds are of Silurian age and may correspond approximately to one of the western horizons, presumably to the Edgewood limestone, as far as may be determined from the meager data secured so far. In that case they belong beneath the *Platymerella* horizon.

This lower Silurian horizon in Ohio may belong beneath the argillaceous horizon for which the name Belfast bed was proposed 27 years ago.<sup>4</sup> At the time this name was proposed two Silurian species were known from the top of the Belfast bed, *Halysites catenulatus*, and a form of *Orthis flabellites* with 44

<sup>2</sup> Foerste, A. F., The Kimmswick and Plattin Limestones of Northeastern Missouri: Denison Univ. Bull. Sci. Lab., vol. 19, 1920, pp. 223, 224.

<sup>3</sup> Savage, T. E., Stratigraphy and paleontology of the Alexandrian series in Illinois and Missouri: Ill. State Geol. Survey, Bull. 23, 1913, p. 36 of reprint.

<sup>4</sup> Foerste, A. F., The Middle Silurian rocks of Ohio and Indiana: Jour. Cin. Soc. Nat. Hist., vol. 18, pp. 163-166, 1896.

radiating plications, probably identical with *Orthis dinorthis* Foerste.<sup>5</sup> These fossils suggest Brassfield affinities. Recently Prof. W. H. Shideler, of Miami University, found specimens of *Whitfieldella* and other fossils having a Silurian aspect in argillaceous strata immediately beneath the typical Belfast bed on Beasley Fork southeast of West Union, Ohio. Their horizon probably is the same as that of the Montgomery county specimens provisionally referred to the Edgewood.

In Montgomery county, Ohio, the upper part of the Brassfield limestone frequently contains interbedded layers of richly fossiliferous clay. Many fossils occur here which are unknown in the underlying parts of the Brassfield limestone, though the more commonly known fossils occur at both horizons. In general, the Brassfield limestone of Ohio, Indiana, and Kentucky appears to correspond to the Manitoulin dolomite of southern Ontario; but the upper, more ferruginous part may correspond approximately to the Cabot Head shale, which, in southern Ontario, is the horizon for *Rhinopora verrucosa*, while the genus *Brockocystis* appears limited to the Manitoulin limestone in that province.

The name Beavertown marl was not intended to designate the richly fossiliferous clay forming the upper part of the Brassfield section or included in the latter locally, but it was used to designate a soft, very fine grained deposit, an argillaceous limestone, readily disintegrating under the influences of weathering, and not a marl in any sense of the term. The term was first used in 1885,<sup>6</sup> and several species, including *Platystrophia reversata*, *Ctenodonta minima*, *Liospira affinis*, *Cyclora alta*, *Bellerophon exiguus*, *Orthoceras inceptum*, and the problematical species designated as *Zygospira modesta* and *Trochonema nanum*, were described from this horizon. The large crinoid beads found in this stratum were of the same type as those found in the upper part of the Brassfield limestone, and the Beavertown marl is

<sup>5</sup> Foerste, A. F., Fossils of the Clinton group in Ohio and Indiana: Ohio Geol. Survey., vol. 7, 1893, pl. 31, fig. 4.

<sup>6</sup> Foerste, A. F., The Clinton Group of Ohio: Denison Univ. Bull. Sci. Lab., vol. 1, 1885 p. 74.

regarded as merely the upper part of the Brassfield formation in this area. A chemical analysis of this so-called marl was published in the series of articles on the Clinton Group of Ohio,<sup>7</sup> the term Clinton at that time being in use for the strata now known as the Brassfield.

In the Hillsboro area, in Highland county, Ohio, the Silurian section consists of the following strata, named in descending order.

Guelph dolomite  
Lilley formation  
Bisher formation  
Alger clay shale  
Dayton limestone  
Brassfield limestone  
Belfast formation

The term Guelph is used here merely to avoid using the term Cedarville dolomite for strata not containing a fauna similar to that of the Cedarville area. It does, however, contain *Megalomus canadensis*, species of *Trimerella*, and other fossils known in the Guelph of Ontario. *Liospira perlata* and tall species of *Coelocaulus* occur.

The base of this so-called Guelph in the quarries in the eastern part of the town of Hillsboro is formed by a *Pentamerus* horizon which corresponds approximately to the Springfield dolomite of Greene, Clarke, Miami, Montgomery, and Preble counties, farther north in Ohio. The overlying part of this so-called Guelph should correspond in age to the Cedarville dolomite of the counties just mentioned, but it does not contain the same fauna.

The Lilley formation includes that part of the section erroneously identified many years ago by Prof. Edward Orton, as the Springfield stone.<sup>8</sup> This identification was based on the lithological appearance of the rock, it forming a promising

<sup>7</sup> Foerste, A. F., The Clinton Group of Ohio;—Part IV: Denison Univ. Bull. Sci. Lab., vol. 3, pp. 3-12, 1888.

<sup>8</sup> Orton, Edward, The Geology of Highland County; Geol. Surv. Ohio, Rep. Progress in 1870. Published in 1871, pp. 274-277.

building stone where exposed along the abandoned railroad within the limits of Hillsboro, and in the quarry in which this railroad, as far as finished, terminated in the eastern part of the town.

The Bisher formation corresponds approximately to the West Union or Lower Cliff of Professor Orton, and this name would have been retained if Professor Orton ever had described any section from the West Union area, or had designated at Hillsboro the same boundaries between the West Union and Springfield beds as those adopted later between the Bisher and Lilley formations. It is of upper Clinton age.

Notes on Bisher and Lilley faunas were published in the *Ohio Journal of Science* in the years 1917 and 1919.

The Bisher fauna can be traced southward from Hillsboro throughout Highland and Adams counties, in Ohio, and Lewis county, Kentucky, as far as the northern part of Fleming county in the latter state. It has not been identified anywhere north of Hillsboro, Ohio, but the strata immediately beneath the Springfield limestone along the creek half a mile west of Port William, in the area northeast of Wilmington, Ohio, appear to contain a somewhat similar fauna. But no trace of the overlying Lilley fauna is to be found so far north.

As a matter of fact, the Lilley fauna appears to be very restricted even in the Hillsboro area. It is known at various quarries in the immediate vicinity of Hillsboro, at several localities southeast of Marshall, and apparently also 2 miles north of Locust Grove, north of Crooked Creek, on the road to Sinking Springs. It has not been identified at any other localities.

While the Bisher formation can be traced over wide areas in Highland and Adams counties, the strata overlying the Bisher formation present a complex of which very little is known so far. The lithologic character of these strata changes within a few miles on proceeding from Hillsboro eastward toward Marshall, and many fossil horizons occur in the areas between Hillsboro, Marshall, Bainbridge, and the Ohio River whose relative position remains to be determined.

Only the Bisher formation is definitely known to occur in Lewis county, Kentucky, though lower portions of the so-called

Guelph may occur there also, for instance, in those Silurian deposits which occur west of Vanceburg on the road to Valley.

The bituminous horizons of the so-called Guelph in the Hillsboro area may be traced northwest of the town on the road to Wilmington, and similar strata, but without the bituminous content, appear to occur near New Vienna, northeast of Snow Hill, in the area between New Vienna and Wilmington, Ohio.

From Wilmington northward, however, the Niagaran section resembles that found in Greene, Clarke, Miami and Montgomery counties. Here the following section is found, in descending order.

Durbin formation	{	Cedarville dolomite
		Springfield dolomite
		Euphemia dolomite
"Laurel" limestone		
"Osgood" clay shale		
Dayton limestone		
Brassfield limestone		
Belfast bed.		

In this section the strata called the Euphemia dolomite are those included by Professor Orton in his West Union bed when using that name for the tier of counties here named. It is the Mottled bed of Professor Prosser. It is frequently exposed between Springfield, Ohio, and Lewisburg, in the western part of the state, but is unknown at Cedarville, where the lowest dolomitic rock in the gorge half a mile west of town belongs to the Springfield horizon.

Immediately beneath this Springfield dolomite, in the gorge west of Cedarville, there is a clay shale, of which a thickness of scarcely 6 feet is well exposed, the basal part not being seen. This clay shale contains, at a level 2 feet below its top, *Streptelasma radicans* Hall, *Eucalyptocrinus crassus* Hall, *Schuchertella subplana* (Conrad), *Leptaena rhomboidalis* (Wilckens), *Plectambonites transversalis* (Wahlenberg), *Dalmanella elegantula* (Dalman), *Spirifer radiatus* (Sowerby), *Atrypa reticularis newsomensis* Foerste, *Dictyonella reticulata* (Hall), *Strophostylus* sp., and *Dalmanites verrucosus* (Hall). This is a Waldron fauna.

The Springfield dolomite in the Springfield area contains relatively few fossils aside from *Pentamerus oblongus* and *Calymene celebra* Raymond. However, at the Jackson quarry, several miles south of Covington, Ohio, the following fauna was found at this level:

*Cyathophyllum* sp., small.

*Cyathophyllum* sp., septa with dentate edges.

*Calostylis* sp.

*Halysites labyrinthicus* (Goldfuss)

*Syringopora* sp., form similar to that found in Cedarville dolomite

*Lichenalia* (?) sp., frequently twisted into more or less tubular growths as in Cedarville dolomite

*Caryocrinus* sp.

*Atrypa reticularis niagarensis* Nettelroth

*Camarotoechia neglecta* (Hall), with relatively sharp plications

*Clorinda ventricosa* (Hall)

*Dalmanella springfieldensis* Foerste

*Leptaena rhomboidalis* (Wilckens)

*Meristina maria* (Hall)

*Orthis fissiplicata* Foerste

*Pentamerus oblongus* Sowerby

*Platystrophia daytonensis* Foerste, with 2 plications in sinus

*Platystrophia* sp., with 4 plications in sinus, found also in Cedarville dolomite at Springfield, Ohio

*Rhipidomella hybrida* (Sowerby)

*Schuchertella subplana* (Conrad), resembling Rochester shale form in its elongate outline

*Spirifer radiatus* (Sowerby), with a few lateral plications

*Strophonella* sp., resembling *Strophonella roemeri* Foerste in being strongly convex and prolonged medially

*Strophonella williamsi* Kindle and Breger

*Cyclonema ohioensis* (Hall and Whitfield), described originally as a variety of *Pleurotomaria pauper*

*Phanerotrema occidens* (Hall)

*Trochonema* sp., large, but with relatively low spire

*Calymene celebra* Raymond

In the Euphemia dolomite, beneath the Springfield dolomite in the Jackson quarry, the following fossils were found:

*Enterolasma caliculum*  
*Favosites* sp.  
*Caryocrinus* sp.  
*Dimerocrinus* sp.  
*Lichenalia* sp. with pseudo-tubular growth, as in Cedarville dolomite  
*Atrypa reticularis*  
*Brachyprion* cf. *newsomensis*  
*Camarotoechia neglecta*  
*Leptaena rhomboidalis*  
*Orthis flabellites*  
*Pentamerus oblongus*  
*Platystrophia daytonensis*  
*Rhipidomella hybrida*  
*Schuchertella subplana*  
*Spirifer radiatus*  
*Stropheodonta* cf. *profunda*  
*Strophonella williamsi*  
*Whitfieldella* sp.  
*Diaphorostoma* cf. *niagarensis*  
*Dalmanites* cf. *limulurus*  
*Illaenus ioxus*

In the Euphemia dolomite, in the large quarry northwest of Lewisburg, the following species occur:

*Enterolasma caliculum*  
*Atrypa reticularis*  
*Leptaena rhomboidalis*  
*Orthis flabellites*  
*Plectambonites transversalis*  
*Schuchertella subplana*  
*Strophonella* sp., strongly convex form  
*Whitfieldella* sp., large  
*Diaphorostoma* cf. *niagarensis*  
*Dalmanites* cf. *limulurus*  
*Illaenus ioxus*

At Ludlow Falls the Euphemia dolomite contains:

Striatopora sp., large form, one-third inch in diameter  
Atrypa reticularis  
Brachyprion cf. newsomensis  
Orthis flabellites  
Pentamerus oblongus  
Platystrophia daytonensis  
Rhipidomella hybrida

*Pentamerus oblongus* is fairly common in the Euphemia dolomite in some of its exposures southwest of Springfield, south of the railroad passing Cold Springs.

The Cedarville, Springfield, and Euphemia dolomites are regarded as belonging to a single formation, characterized by the fact that at a certain horizon, known, as the Springfield dolomite, the rock is separable readily into flagging, suitable for building purposes, while the Euphemia dolomite below and the Cedarville dolomite above are not suitable for flagging. The term Durbin formation is used for this formation as a whole.

At the Reinheimer quarry, south of New Paris, the so-called Laurel limestone contains *Pisocrinus gemmiformis*, and *Stephanocrinus osgoodensis*. The same species occur in the abandoned James Carl quarry,  $3\frac{1}{2}$  miles southwest of Lewisburg, up a small stream west of the road to Eaton. They occur at a number of other localities in Preble county, Ohio. In Indiana both species occur in the Osgood limestone, but *Pisocrinus gemmiformis* is cited also from the lower part of the Laurel limestone. At the quarry west of Drexel Park,  $\frac{3}{4}$  of a mile east of the Union road, north of the Eaton pike, *Pisocrinus gemmiformis* occurs in coarse-grained rock immediately beneath the Springfield limestone, assumed to be of Euphemia age. Immediately above the argillaceous strata which form the base of the exposed section along the creek a mile east of Leesburg, and north of the railroad, *Stephanocrinus gemmiformis* and *Stephanocrinus ham-melli* were found in strata apparently belonging to the Bisher formation. Small species of *Pisocrinus* and *Stephanocrinus*, difficult to discriminate except in the presence of good speci-

mens, have a considerable vertical range in the Niagaran, and the specimens found so far at different localities and horizons in Ohio are regarded as inadequate for purposes of exact correlation. For the present, therefore, the so-called Laurel limestone of western Ohio must be regarded as identified lithologically, rather than paleontologically with the typical Laurel of Indiana.

The same statement can be made regarding the so-called Osgood clay shale of Ohio. This has been identified lithologically with a clay shale band well exposed in the upper part of the quarries southwest of Laurel, Indiana, but the fauna found in these so-called Osgood clay shales in Ohio is that of the underlying Dayton limestone, and not that of the typical Osgood formation in Ripley and Jefferson counties, in Indiana.

In the large quarry northwest of Lewisburg, Ohio, the top of the Dayton limestone contains the species usually identified as *Enterolasma caliculum* (Hall), *Atrypa reticularis* Linnaeus, *Spirifer radiatus* (Sowerby), and a *Spirifer* intermediate between *niagarensis* (Conrad) and *eudora* (Hall) in the number of its radiating plications. The middle part of the Dayton limestone here contains *Enterolasma caliculum*, *Orthis flabellites* Foerste, *Plectambonites transversalis*, *Spirifer plicatellus* Linnaeus, *Schuchertella subplana* (Conrad), and a small species of *Whitfieldella*, similar to the one most common in the Osgood and Laurel limestones of Indiana.

At Rocky Point, 3 miles northeast of Eaton, on the road to Lewisburg, the Osgood clay, overlying the Dayton limestone is 4 feet 3 inches thick, and contains the following species: *Enterolasma caliculum*, *Atrypa reticularis*, *Leptaena rhomboidalis*, *Orthis flabellites*, *Schuchertella subplana*, and the same species of *Spirifer* as that cited from the top of the Dayton limestone at the quarry northwest of Lewisburg.

From Trotwood  $2\frac{1}{2}$  miles southward and  $1\frac{3}{10}$  miles east, the following fossils are found in the Dayton limestone: *Enterolasma caliculum*, *Rhinopora* sp., *Clathrodictyon vesiculosum*, *Camaro-toechia neglecta*, *Leptaena rhomboidalis*, *Orthis flabellites*, *Platystrophia daytonensis*, *Platystrophia reversata*, and *Rhipidomella hybrida*.

At the abandoned quarry north of the Germantown pike, near the southeast corner of the Soldiers Home, west of Dayton, the following fossils are found in the Dayton limestone: *Enterolasma caliculum*, *Favosites niagarensis*, *Clidochirus ulrichi*, *Chasmatopora angulata*, *Rhinopora verrucosa*, *Coelospira* sp., *Leptaena rhomboidalis*, *Orthis flabellites*, *Platystrophia reversata*, and *Rhipidomella hybrida*.

In the quarries southeast of Dayton, and thence south and eastward, brachiopoda are scarce in the Dayton limestone, with the exception of *Pentamerus oblongus*, which is rare until the southern margin of Clinton county is reached, but which becomes common in parts of Highland and Adams counties, and reaches even the northern part of Lewis county, in Kentucky. In the eastern half of Montgomery county, and in Miami, Clarke, and Greene counties little is seen in the Dayton limestone in addition to *Favosites favosus*, *Favosites niagarensis*, and various species of *Orthoceras*, not determined.

Beginning at Centerville, and increasing in numbers at Todd Fork, north of Wilmington, additional species of corals, simple and compound, appear, reaching their maximum in Highland and Adams counties, where more than 20 species are known. The range of these corals continues into the northern part of Lewis county.

This change of fauna from a brachiopod fauna in western Ohio to a coral fauna southeastward along the line of outcrop, is the most significant feature noted so far in the distribution of the faunas of the Dayton limestone.

In Indiana, the limestone layer underlying the typical Osgood formation of that state, usually only one or two feet thick, is correlated with the Dayton limestone of Ohio, but the Indiana limestone layer is practically unfossiliferous, and the few species found have not belonged to diagnostic forms, so that they do not serve for purposes of accurate correlation.

In fact, all of the Ohio Niagaran strata present difficulties when the attempt is made to correlate them accurately with the Niagaran strata of Indiana.

While the Dayton, Osgood, and Laurel strata of Montgomery, Miami, Darke, and Preble counties bear considerable resemblance to the corresponding sections in the area immediately southwest of Laurel in Indiana, the so-called Osgood of Ohio does not carry the typical Osgood fauna of Ripley and Jefferson counties in Indiana, and the so-called Laurel of Ohio does not carry the Laurel fauna so well known in the St. Paul and Waldron areas of Decatur and Shelby counties of Indiana.

No equivalent to the Euphemia and Springfield strata is known at present in Indiana. The Cedarville dolomite of Ohio carries a fauna much nearer that of the Racine of Wisconsin and northern Illinois than that of the Louisville limestone of southern Indiana and northern Kentucky. The upper Niagaran strata of the eastern counties of Indiana carry faunas much nearer that of the Wabash area of northern Indiana than that of the Cedarville of Ohio, or the Louisville of the southern part of Indiana. Finally, the upper Laurel fauna of St. Paul has its affinities rather in the Racine faunas of Wisconsin and northern Illinois than in anything known in Ohio.

In other words, the evidence is accumulating that the Silurian strata of Ohio, Indiana, and Kentucky present a much greater complex of faunas than would be supposed by the simple alternation of limestone and clay zones in the various areas. While those unacquainted with the faunas will readily match limestones and clays of one area with limestones and clays of another area, notwithstanding great differences in faunal content, the paleontologist is not so ready to follow this procedure. In our present state of knowledge of the Niagaran faunas, most of our correlations are worth very little, and must be considered merely tentative. There is a great lack of knowledge of the content and geographical range of the various faunas. Until this lack is supplied by accurate information, substantial progress is impossible. Detailed paleontological work on Silurian strata in Ohio, Indiana, and Kentucky has practically ceased, and until serious study again is undertaken no vital progress can be expected.

## B. THE FAUNA OF THE WHIRLPOOL SANDSTONE OF ONTARIO

Very little is known of the fauna of the Whirlpool sandstone, the lowest member of the Medinan in southern Ontario. In 1919 Dr. M. Y. Williams<sup>9</sup> listed only the following species from this sandstone:

## Gasteropoda

*Pleurotomaria* sp. Niagara River

*Hormotoma subulata* (Conrad) ?? Glen William

Vermes (burrows and trails)

? *Cornulites*

From the Grimsby sandstone, in the upper part of the Medinan, he listed:

## Brachiopoda

*Lingula cuneata* Conrad

*Lingula clintoni* Vanuxem

*Dalmanella eugeniensis* Williams

*Camarotoechia* (*Stegerhynchus*) *neglecta* Hall

## Pelecypoda

*Pterinea* cf. *undata* (Hall)

*Pterinea brisa* Hall

*Modiolopsis primigenia* (Conrad)

*Modiolopsis orthonota* (Conrad)

*Modiolopsis kelsoensis* Williams

*Ctenodonta machaeriformis* (Hall)

*Nuculites* cf. *ferrugineum* Foerste

## Gasteropoda

*Bucanella trilobata* (Conrad)

From the overlying Thorold sandstone, at the top of the Medinan, he listed:

## Worm burrows

*Daedalus archimedes* (Ringueberg)

*Arthropycus alleghaniensis* (Harlan)

<sup>9</sup> Williams, M. Y., *The Silurian Geology and Faunas of Ontario Peninsula and Manitoulin and Adjacent Islands: Memoir 111, Geol. Surv. Canada, p. 28, 1919.*

To the brief list of fossils from the Whirlpool sandstone published by Dr. Williams we here add a few obtained in the quarry a quarter of a mile west of the railroad station at Credit Forks, in southern Ontario. This quarry is located immediately north of a deep ravine crossing the railroad south of the station. The fossils were found in thin sandstone layers at the top of the Whirlpool sandstone, immediately under the basal layers of Manitoulin dolomite, in which specimens of *Leveilleites* were found. Several of these additional species from the Whirlpool sandstone evidently are merely earlier occurrences of forms already known from the Grimsby sandstone, in the upper part of the Medinan.

While some of these specimens are not sufficiently well preserved to serve as types of new species, they clearly indicate the presence in the Whirlpool sandstone of a much larger fauna than suspected formerly.

The list of species from the Whirlpool sandstone at Credit Forks is as follows:

1. *Lingula* cf. *cuneata* Conrad
2. *Dalmanella eugeniensis* Williams
3. *Schuchertella creditensis* Sp. nov.
4. *Whitfieldella circularis* Sp. nov.
5. *Modiolopsis orthonota creditensis* Var. nov.
6. *Ctenodonta* (?) sp.
7. *Ctenodonta* (?) *creditensis* Sp. nov.
8. *Ctenodonta* (?) *cataractensis* Sp. nov.
9. *Liospira* (?) sp.

1. *Lingula* cf. *cuneata* Conrad

*Plate XIII, fig. 9*

*Lingula cuneata* Conrad, 3d Ann. Rep. Geol. Surv. New York, 1839, pp. 63, 64; Hall, Pal. New York, 2, 1852, p. 8, pl. 4, fig. 2e.

Specimen 10 mm. long, 6.5 mm. wide, ovate in outline, and pointed toward the beak; with a convexity slightly exceeding 1 mm. The general outline agrees more closely with that of figure 2e on the plate in the Paleontology of New York, cited above,

than with the more triangularly cuneate specimens represented by figures 2a, 2b, and 2c on the same plate.

## 2. *Dalmanella eugeniensis* Williams

*Plate XIII, fig. 7*

*Dalmanella eugeniensis* Williams, Geol. Surv. Canada, Memoir 111, 1919, p. 118, pl. VII, figs. 1-8.

Specimen a brachial valve, 7.5 mm. long, and 9 mm. wide; most strongly convex about 1.5 mm. from the beak, with a narrow median depression posteriorly, widening to a broad depression along the anterior half of the valve. About 8 radiating striae reach the anterior margin of the valve in a width of 3 mm., the total number on the valve being between 40 and 45.

## 3. *Schuchertella creditensis* Sp. nov.

*Plate XIII, fig. 6*

Cf. *Leptaena subplana* Hall, Pal. New York, 2, 1852, p. 259, pl. 53, figs. 8a, 8b.

Pedicle valve 15.5 mm. long, 18.5 mm. wide, with a convexity of almost 2 mm. at a point 5 mm. anterior to the beak. The valve is gently convex, without any trace of reversal of curvature anteriorly. At the posterior margin of the valve the lateral sides curve gently inward. Along the anterior margin, 7 to 8 radiating striae occur in a width of 3 mm., the alternate striae being distinctly more prominent. Along the postero-lateral margins this alternation of size is even more evident. The dental lamellae are nearly 3.5 mm. in length and diverge from each other at an angle of about 80 degrees.

The largest specimen found was 21 mm. in width.

Several small brachial valves, regarded as belonging to the same species, are much less convex than the pedicle valve here described.

#### 4. *Whitfieldella circularis* Sp. nov.

*Plate XIII, figs. 8 A, B*

Cf. *Atrypa oblata* Hall, Pal. New York, 2, 1852, p. 9, pl. 4, figs. 4 a, b, c, and 5. Cf. *Whitfieldella cataractensis* Williams, Geol. Surv. Canada, Memoir 111, 1919, p. 121, pl. 7, figs. 16, 17, 18.

One brachial valve (fig. 8 A) is 11.3 mm. long, 10.5 mm. wide, and 3 mm. deep. It is quite evenly convex, except at the margins where it curves more rapidly. Concentric lines are seen near these margins. A median septum in the interior of the valve extended about 3 mm. from the beak.

A second brachial valve (fig. 8 B) is 9.3 mm. long, 9.2 mm. wide, and 2.3 mm. deep. The median septum on its interior is 2.5 mm. long.

These valves do not appear to be the young of *Whitfieldella oblata* (Hall), from the Upper Medinan of Lockport, New York. The first of the two specimens here described appears quite mature, judging from its convexity along its margins. Nor is it identical with *Whitfieldella cataractensis* Williams.

#### 5. *Modiolopsis orthonota creditensis* Var. nov

*Plate XIII, figs. 1, 2 A-G*

*Modiolopsis orthonota*, Pal. New York, 2, 1852, p. 10, pl. 4 (bis), figs. 1 a-c.

Numerous valves, of which the largest is 21.5 mm. long, 10.6 mm. high, and 2.5 mm. deep. Specimens 16 to 18 mm. long are much more common. The cardinal and ventral margins tend to converge posteriorly. In one specimen 18 mm. long, the height of the specimen at the beak is 9 mm., while 10 mm. posterior to the beak it is 8 mm. in height. This appearance of convergence posteriorly is due in part to the rise of the umbonal part of the valves above the hinge-line. The posterior part of the ventral margin rises convexly as far as the posterior termination of the umbonal ridge, and from this point the posterior margin of the valve curves strongly forward at an angle of about

120 degrees with the cardinal margin. Along this part of its outline the posterior margin usually is only moderately convex, there being a distinct tendency toward straightening. The anterior part of the valve extends from 3.5 to 4 mm. in front of the beak. It is fairly evenly convex, its maximum convexity appearing slightly below mid-height of the valve, on account of the slight inward curvature of this outline on approaching the umbonal part of the valve. The umbonal part is relatively broad, and only slightly elevated above the cardinal margin. The umbonal ridge is sigmoidal in direction, starting near the beak at a small angle with the cardinal margin, this angle increasing to 20 and 25 degrees near mid-length of the valve, and then decreasing again posteriorly as far as the posterior angle of the valve. The post-umbonal slopes of the valves are distinctly concave, but the umbonal ridge tends to be rounded, rather than angular. In most specimens the middle part of the valves, beneath and anterior to the umbonal ridge, is gently convex antero-posteriorly, with a tendency toward flattening where the mesial sulcus might appear, this sulcus usually being absent, though faintly indicated occasionally.

Remarks.—These specimens from the Whirlpool sandstone at Credit Forks, Ontario, differ from typical *Modiolopsis orthonota* from the Grimsby sandstone at Lockport, and Medina, New York, in the greater angulation of the posterior side of the umbonal ridge and in the more distinctly concave curvature of the post-umbonal slope, between the umbonal ridge and the hinge-area.

Owing to its more angular umbonal ridge, the specimen represented by figure 1 on plate XIII may be designated as *Modiolopsis orthonota perumbonata* Var. nov.

In the type specimens of *Modiolopsis orthonota* that part of the shell which corresponds to the angular part of the umbonal ridge of the Credit Forks specimens is more evenly rounded while the distinctly concave part is narrower, its lower margin deviating only 2.5 mm. from the hinge-line at the posterior end of the shell. Immediately beneath the beak of the right valve the hinge-area appears to have been slightly elevated in a more or

less vertical direction, while a corresponding elevation occurred immediately in front of the beak of the left valve. The elevations may be regarded as incipient teeth. (Plate XIV, figs. 7 A, B.)

The fauna described by Hall from strata 50 to 60 feet below the top of the sandstone at Medina includes *Lingula cuneata*, *Modiolopsis orthonota*, *Modiolopsis primigenia*, *Pleurotomaria pervetusta* and *Bucanica trilobita*. This appears to be a Grimsby sandstone fauna. *Modiolopsis primigenia* is represented by fig. 8 on plate XIV.

6. **Ctenodonta** (?) sp.

*Plate XIII, fig. 5*

A single left valve, 6.6 mm. long, 4 mm. high, and 1.3 mm. deep, resembling *Modiolopsis orthonota* in outline, but without any trace of concave curvature along a distinctly defined post-umbonal slope. In fact, there is no distinctly defined post-umbonal slope, the valve rounding from the general convexity of its middle parts into a more increased convexity along the posterior cardinal margin of the shell without any interruption whatever. In specimens of *Modiolopsis orthonota* of the same size the post-umbonal slope is distinctly defined and is distinctly concave.

7. **Ctenodonta** (?) **creditensis** Sp. nov.

*Plate XIII, fig. 3*

Three valves in which the ratio of the height to the length varies from 71 to 76 per cent are at hand. In the two larger specimens the posterior part of the outline is defective. One of the specimens (fig. 3) is 8.5 mm. in height, and its length is estimated at 11.8 mm. In the other one of the larger specimens the height is 7.5 mm., and the length is estimated at 10.5 mm. The third specimen is 4.2 mm. in height and 55. mm. in length. The larger specimens are 2 mm. in depth. The anterior parts of these valves are similar to those of *Modiolopsis orthonota*, but the beak is more pointed and is directed more distinctly toward the front, and the upper half of the anterior outline, anterior to

the beak, is more distinctly concave. Posterior to the beak there is no trace of an umbonal ridge, the convexity of the valves increasing toward the cardinal margin. The posterior margin of the valves is similar to that of a relatively short *Ctenodonta*.

8. *Ctenodonta* (?) *cataractensis* Sp. nov.

*Plate XIII, fig. 4*

Left valve 7.3 mm. long, 5.5 mm. high, and 1.5 mm. deep. General outline elliptical, with the longer axis in a horizontal direction, but with the beak sufficiently elevated to add a slight triangularity to the elliptical outline. The beak is about 3 mm. from the anterior margin. The outline posterior to the beak is convex as far as the posterior angle of the valve. The outline anterior to the beak is almost imperceptibly concave. The ventral outline is evenly convex along the greater part of its length, this convexity increasing toward the extremities of the valve, where the outline is most rapidly rounded. The maximum depth of the valve is about 2 mm. below the beak.

9. *Liospira* (?) sp.

*Plate XIII, fig. 11*

Specimen with a maximum transverse diameter of 5 mm., consisting of at least two volutions. Evidently only a part of the shell is preserved, the number of additional volutions in a mature specimen being unknown. The spire is depressed, very much as in *Liospira micula* (Hall), from the Ordovician. The outer margin is narrowly rounded, also as in *Liospira micula*, and not elevated as in *Pleurotomaria* (?) *pervetusta* (Conrad), in which the height of the spire and of the individual volutions is much greater. With only a single specimen at hand it is impossible to determine with confidence either its relationship to, or its difference from *Pleurotomaria pervetusta*. It may be the apical part of the latter species.

**Straparollus (?) pervetustus (Conrad)***Plate XIV, fig. 6*

Cyclostoma ? pervetusta Conrad, Ann. Rep. New York State Geol. Surv., 1838, p. 113; *ibid.*, 1839, p. 65.

Pleurotomaria pervetusta Hall, Pal. New York, 2, 1852, p. 12, pl. 4 (bis), figs. 3 a-d.

Euomphalus pervetustus Hall, Geol. New York, 4, 1843, p. 48, figs. 1, 2; tab. ill. 2, figs. 1, 2.

Straparollus pervetustus D'Orbigny, Prod. de Pal., 1, 1849, p. 30 (gen. ref.).

Euconia (?) pervetusta Grabau and Shimer, N. A. Index Fossils, 1, 1909, p. 642, fig. 874.

Shell 9 mm. wide and 7.5 mm. in height, with the spire rising 3 mm. above the last whorl near the aperture. In the specimen figured by Hall the width is 8 mm., the height is 6 mm., and the elevation of the spire above the aperture is about 2.5 mm. The vertical outline of the spire is rounded, the lowest volution permitting slightly more than half of the preceding volution to be seen, while toward the apical end less and less of the preceding volutions remains visible. About five volutions are present. Viewed from the exterior of the shell, these volutions appear circular in cross-section, but along vertical sections of the shell it is seen that later volutions are in contact with earlier volutions in such a manner that the inner half of the upper outline of the lower volution comes in contact with the outer half of the lower outline of the preceding volution along a lunate curve with its concave side facing upward and inward. Toward the aperture this lunate line of contact may be 2.5 mm. in width. At the base of the specimen there is an umbilicus 1 mm. in diameter. It is not known to what extent the interior of the umbilicus is lined by a callous deposit, if any be present. No trace of surface markings of any kind have been discovered.

Locality and formation.—At Medina and Lockport, in the Grimsby sandstone member of the Medinan.

Remarks.—Until traces of a slit-band are discovered in this species it seems inadvisable to refer it to *Pleurotomaria* or to

any of the Pleurotomariidae. It does not possess the conical spire of *Euconia*. Externally it resembles such forms as *Straparollus hippolyta* Billings, and *Straparollus mopsus* Hall, but its umbilicus is much smaller. While the relationship of this species to *Straparollus* must remain in doubt, in the absence of any knowledge of the surface features, it is not out of place to refer to the absence of definite knowledge of any structure indicating affinities with the Pleurotomariidae.

C. FOSSILS FROM THE BASE OF THE MANITOULIN LIMESTONE AT  
CREDIT FORKS, ONTARIO

For many years it has been customary to refer certain flat branching structures found in Ordovician and Silurian strata to the algae. Some of these, in more recent years, have been regarded as due to worm borings, worm tracks, and even to the cutting action of flowing water. Those, however, which consist of thin black films can not be passed over so lightly, and must be regarded as at least of organic origin.

The black coloring of the latter specimens usually is regarded as due to plant origin, being derived in a manner analogous to the derivation of coal from plant material.

Usually this black material, in the plant-like organisms found in Ordovician and Silurian strata, does not present any structure.

In the summer of 1911, however, the writer found numerous fragments of plant-like fronds in one of the quarries at Credit Forks, in southern Ontario, Canada, which under the microscope presented distinct, though limited evidence of structure. During the geological congress held in the summer of 1913 the writer served as guide to a small party of geologists, and on this occasion Chris Andrew Hartnagel of the Geological Survey of New York and Dr. E. O. Ulrich of the United States Geological Survey found the remarkable specimen here described as the type of the genus *Leveilleites*.

At first these frondose specimens were regarded as belonging to the algae, and an attempt was made to find algal forms with corresponding outlines. The reticulating fibers forming the body of the fronds were interpreted as corresponding to the

filaments or laciniae which traverse the interior of some of the more fleshy algae.

However, the fibrous structures traversing the interior of algae possess such a small quantity of carbon that it is difficult to conceive how they could remain in a fossil form as anything but the thinnest imaginable traces. In *Leveilleites*, on the contrary, they appear like fibers which had not given way to pressure. In fact, they appear more like fibers of sponges than of fibers which could have originated from algae.

Moreover, in the frondose fleshy algae it seemed reasonable to expect occasional traces of organs of reproduction, in the form of swellings of the fronds or other structures of sufficient size to warrant their recognition even in fossil form, but nothing of the kind was discovered among the numerous specimens examined.

In fact, as more material accumulated, the plant origin of these frondose organisms found at Credit Forks seemed less certain, and the possibility of their being of animal origin less doubtful.

The reference, in preceding lines, to fibers of sponges is not intended to suggest that *Leveilleites* may be some early type of sponge. It is possible that some other form of animal life with more or less fibrous material within its structure, not yet clearly recognized, may have existed in Ordovician and Silurian times.

Since these frondose organisms found at Credit Forks present more structure than any similar flat plant-like bodies found heretofore, they are described and figured in much greater detail than otherwise would prove desirable. In the twelve years which have elapsed since their discovery, no additional information has been added as the result of further study either of old material, or material accumulated more recently. Therefore, it does not seem advisable to withhold the publication of these observations any longer.

To the account of *Leveilleites* is added a description of *Dictyonema scalariforme creditensis*, Foerste found in the same slabs of rock as *Leveilleites*. Several species of fossils found in the

Whirlpool sandstone, directly beneath the layers containing the *Leveilleites*, have been described already, on preceding pages.

***Leveilleites* Gen. nov.**

Specimens consisting of linear-oblong frond-like expansions attached to a more or less twisted stipe. Each lateral margin of these frond-like expansions is formed by a single series of lobes, the lobes being small, and those belonging to the same expansion being approximately of the same form and size.

The frond-like expansions are flat and thin. Their median line, when the specimens are well preserved, is occupied by a narrowly linear black film within which no structure has been observed. In some specimens corresponding films occupy the median part of the lateral lobes. The significance of these linear black films is unknown. Although they occupy the position of a rachis, they apparently do not locate a line of thickening of the frond.

The lateral parts of the frond-like expansions, as far as any structure has been observed, consist of fibers, more or less irregularly arranged. In most specimens these fibers anastomose more or less irregularly, but in a few many of the meshes are approximately of the same size, usually not exceeding 0.25 mm. in diameter. Where the narrowly linear black film along the median line of the frond-like expansions is absent, the fibrous structure characterizing the lateral parts of these expansions is seen. This adds to the difficulty of finding a reasonable interpretation of the significance of the linear median black films. In some specimens, the fibers belonging to the lateral parts tend to radiate more or less on approaching the margins of the lobes.

The entire surface of the frond appears to be covered by a coat of very fine hair-like fibers. These fibers are seen most readily along the margins of the lobes, beyond which they project outward a distance varying from less than 1 mm. to fully 1.5 mm. The finer fibers number here from 5 to 7 or 8 in a width of 0.5 mm.

In some specimens, black dots are seen in addition to the anastomosing black fibers within the body of the frond-like

expansions. These black dots tend to occur in rows, about 5 or 6 in a width of 0.5 mm. Possibly these black dots locate extensions of some of the anastomosing fibers, and served as supports of very fine hair-like fibers, similar to those seen along the lateral margins of the fronds. This appears to be confirmed by some specimens in which some of the hair-like fibers extending beyond the margins of the lobes can be traced at their proximal ends to dots located some distance back from these margins, along the flat faces of the fronds.

Similar hair-like fibers cover the surface of the dichotomously branching frond-like expansions occurring in the Cayugan of the Buffalo area of New York, and in the Kokomo formation of northern Indiana. These Upper Silurian frond-like expansions usually are referred to *Buthotrephis*, a genus originally described from the Chazy and Trenton of New York.

While it is customary to refer these Upper Silurian forms of *Buthotrephis* to the algae, it should be remembered that no evidence of structure within the frond or of characteristic forms of reproduction have yet been adduced in proof of this view.

The black coloring of the specimens of *Buthotrephis* from the Buffalo and Kokomo areas usually is regarded as evidence of plant origin, the black coloring being regarded as being derived from plant material, like coal. However, it is exceedingly doubtful whether such minutely fibrous structures as those here described in *Leveilleites* ever could have had a plant origin, considering the perfection of their preservation.

Under a microscope, the fibers of *Leveilleites* are seen to pass between the minute sand grains forming the matrix as though these fibers had some measure of stiffness at the time of their burial in the sea mud. Apparently they were more or less free from other material.

These fibers resemble the fibers of sponges more than those of plants. However, even if of animal origin, the fronds of *Leveilleites* show no trace of oscula or of other characteristic structures of sponges. Possibly they belong to some group of animals not yet discriminated from those recognized so far.

Among the living algae most closely resembling the fronds of *Leveilleites* in general outline are *Leveillea jungermannoides* (Mart. & Her.) Harvey and *Polyzonia elegans* Suhr. Both belong to the family Rhodomelaceae of the class Rhodophyceae, or Red Algae and both occur in the waters off Mauritius. The first of these species is figured by Engler and Prantl in *Die Natürlichen Pflanzenfamilien* (I Theil, 2 Abtheilung), on page 463 of their volume on Algae, a generic description being given on the following page. Since the resemblance in general outline is quite striking, the term *Leveilleites* is here proposed for the Canadian frond-like expansions here described, without intending to convey any belief that these Canadian forms are algae.

The genus *Caulerpa*, belonging to the class Chlorophyceae, or Green Algae, also presents lobate frondose expansions; this is true especially of *Caulerpa crassifolia* (Ag.) J. Ag., shown on page 136 of Engler and Prantl, but this is a much larger form than *Leveilleites*.

Among Hepaticae, there are foliose species of *Calypogeia* (= *Kantia*), *Lophocolea*, *Chiloscyphus*, etc., but Hepaticae probably were not in existence in Silurian times; at least they are not known to have occurred in the Silurian.

The genotype of *Leveilleites* is *Leveilleites hartnageli* Foerste.

***Leveilleites hartnageli* Sp. nov.**

*Plates IV-XI*

Type.—Specimen (plate IV, fig. A) 70 mm. in length, consisting of a stipe over 40 mm. in length, to which 12 or more frond-like expansions are attached. The frond-like expansions are about 20 mm. in length and from 3 to 4 mm. in width. The median line of the expansions is occupied by a narrowly linear black film, from one-third to two-fifths of a millimeter in width. In its present state of preservation, the divisions between the lateral lobes continue almost or quite to the continuous median black film. The number of lateral lobes of the frond-like expansions varies from 6 to 8 in a length of 10 mm., 7.5 lobes being the most frequent number.

This type specimen is associated on the same slab with *Dictyonema scalariforme creditensis* Foerste, and was found in the basal part of the Manitoulin dolomite, directly over the Whirlpool sandstone, the two lower members of the Medinan formation in southern Ontario. It was found in the quarry a quarter of a mile west of Credit Forks station, on the northern side of the deep valley which crosses the railroad south of the station. Here the Whirlpool sandstone forms the base of the quarry, and *Leveilleites* occurs in fair abundance in the basal layers of the Manitoulin dolomite, which here is quarried extensively.

Associated with *Leveilleites* in other slabs from the same locality and horizon are *Leptaena rhomboidalis* Wilckens and a species of coral resembling *Enterolasma facetus* Foerste in size and form. The *Leptaena* is 23 mm. in width. The coral is 25 mm. in length, measured along its convex side, and 15 mm. in diameter at the top. It is curved at the base very much as in figure 5, plate V, of Dr. M. Y. Williams' memoir.<sup>10</sup> These fossils indicate the marine character of the deposits containing *Leveilleites*.

The type of *Leveilleites hartnageli* belongs to the collection of C. A. Hartnagel, a member of the Geological Survey of New York. The reverse of the same specimen belongs to the collection of Dr. E. O. Ulrich, of the United States National Museum.

The species is named in honor of Mr. Hartnagel, one of the original collectors.

Similar specimens.—Among the numerous separate fronds of *Leveilleites* found at the type locality and horizon, those represented by figures 4, 5, 6, 11, and 12 on plate V are similar in presenting 6 to 8 strongly divided lobes in a length of 10 mm.; figure 26 on plate IV is the reverse of figure 5 on plate V. Specimen 5 is represented also on plates VII and X, and specimen 26 is represented also on plate VII.

In specimen 4 the lobes are convexly curved on the side exposed to view, and they evidently are continuous laterally, the

<sup>10</sup> Williams, M. Y., The Silurian Geology and Faunas of Ontario Peninsula and Manitoulin and Adjacent Islands: Geol. Surv. Canada, Memoir 111, 1919.

appearance of separation being due chiefly to the presence of matrix along the depressed parts of the frond.

Of specimen 5 both the obverse and reverse are present. The lobes are distinctly separated, and incline so that the upper margin of each lobe is at a higher level than the lower margin of the next lobe, when the frond is held horizontally. Hair-like fibers extending from the margins of the lobes for a distance of 1 mm. are numerous, and some of these are directed distinctly at an angle with the plane of the lobes. Apparently these hair-like fibers were attached in part to the flat faces of the lobes. Six occur in a width of 0.5 mm. Reticulation among the fibers forming the lobes is present. Series of minute dots may be recognized among the reticulating fibers. These served as points of attachment for the hair-like fibers.

Specimen 6 presents a median, rachis-like film 0.4 mm. wide. The lobes slope, as in the preceding specimen. The hair-like fibers attached to the flat surface of the fronds are clearly shown, and several of these are replaced by rows of distinct black dots, 7 or 8 in a length of 0.5 mm., interpreted as denticulations on the lateral margins of these fibers. Viewed from the side, the reticulating fibers forming the fronds present approximately circular, rather than flattened cross-sections.

Specimen 11 shows a tendency toward distinct lobes. Both reticulated and hair-like fibers are present. In addition there are several rows of black dots. Some of the hair-like fibers appear to arise from these dots and to extend beyond the margin of the frond.

Specimen 12 presents similar rows of black dots, both among the reticulated and among the hair-like fibers. Among the latter the dots are distinctly smaller. Of the larger black dots in the frond 6 occur in 1 mm.; on the hair-like fibers 5 to 7 dots occur in 0.5 mm. Some of the hair-like fibers are 1.5 mm. long.

Specimens with more numerous lobes.—In the specimens represented by figure 3 on plate V and figure 20 on plate VI, more numerous lobes occur, than in the specimens described so far. The first of these specimens exposes several fronds with 9 or 10 lobes in a length of 10 mm.; the second has 11 lobes in the same length.

Specimen 3 is represented by both the obverse and reverse parts. In specimen *B* the lateral margins of the lobes appear confluent. In several small fragments between *A* and *B* the lobes are conspicuously separated from one another; possibly only the median parts of these lobes are preserved. In *B*, the rachis-like median film is 0.5 mm. wide. The reticulating fibers appear to radiate more or less toward the margin of the lobes. Numerous hair-like fibers, 1 mm. in length, extend beyond the margin of the frond. Among the reticulating and hair-like fibers there are rows of black dots, those among the hair-like fibers being smaller.

In specimen 20, the left margin of the frond is distinctly lobed, while the right margin is only crenulated. Apparently the marginal parts of the lobes are not well preserved on the distinctly lobed side. Rows of black dots appear both among the reticulated and among the hair-like fibers.

Appearance of lobation sometimes deceptive.—Some specimens which on macroscopical examination appear strongly lobed, on microscopical examination appear less indented, the lateral parts of the supposed lobes being confluent, the lobation being confined to marginal crenulations. Specimens of this type are represented by figures 1, 7 A, 8, 9, and 10 on plate V, and by figures 18 B and 21 on plate XI. Additional figures of specimens 8, 18 B, and 21 are found on plates VIII, XI, and IX respectively.

Frond A on specimen 1 presents very well the median black rachis-like film. Rows of black dots are very distinct, varying from 6 to 9 in 1 mm.

Specimen 8 shows very well the median rachis-like film of the frond, 0.4 mm. wide. The fibers within the frond form relatively coarse and irregular meshes. Along the central part of the frond, black dots occur in series, 5 or 6 in 0.5 mm. The hair-like fibers extend 1 mm. beyond the margin of the frond. Black dots along these hair-like fibers number 6 or 7 in 1 mm. The hair-like fibers probably were attached both to the margin of the frond and to its flat faces.

Specimen 10 shows very well the reticulation among the fibers forming the body of the frond. The hair-like fibers extending beyond the margin of the frond are also well preserved. Specimen 18 B exposes very well some of the hair-like fibers near the lateral margin of the frond. The appearance of lobation is due to oblique wrinkling. Frond B on specimen 18 is one of the best specimens to suggest the presence of reticulations among the fibers of the frond. Near the median line of the frond 3 meshes occur in a length of 1 mm.; at a greater distance from the median line they are more irregularly arranged. Of the larger black dots, 5 occur in a length of 1 mm. Specimen 21 shows along its right margin several of the series of black dots regarded as locating the direction of some of the hair-like fibers.

In specimen 23 the right hand frond is seen under the microscope to be crenulated rather than lobed, the appearance of lobation being due in part to a twisting of the frond near the inner angles of the points of indentation. The median rachis-like film is poorly preserved, but may be traced readily. Reticulation among the fibers of the frond is evident. The hair-like fibers extend more than 1 mm. beyond the margin of the frond, and some of them may be traced to points of attachment on its flat surface.

In specimen 22 the rachis-like film of the median part of the frond is 0.6 mm. wide, the corresponding parts of the lateral lobes being 0.25 mm. wide. The reticulated fibers produce meshes from 0.2 mm. to  $\frac{1}{3}$  mm. long. Along some of the hair-like fibers there are 6 or 7 dots in a length of 0.5 mm.

In specimen 24 the main rachis is 0.6 mm. wide, while the corresponding parts of the lateral lobes are 0.4 mm. wide. The latter are so well preserved that on macroscopical examination the frond appears lobed, while microscopically the frond is seen to be merely crenulated.

Specimens with crenulated margins.—Specimens with the lateral margins of the frond-like expansions crenulated rather than lobed are so common that eventually they may be regarded as more normal than the lobed specimens of *Leveilleites*. Specimens with crenulated edges are represented by figures 2, 3A,

and 7B on plate V, by figures 13, 14, 15, 16, 17, 18A, 19, and 21A on plate VI, and by figure 25 on plate IV. Additional figures of 3A, 21A, and 25 are presented on plates VII and IX.

In specimen 2 the median rachis-like film is 0.4 mm. in width. Among the reticulating fibers several series of black dots number 6 or 8 in a length of 0.5 mm. Hair-like fibers extending beyond the margin of the frond are well shown.

Specimen 3A shows traces of the median rachis-like film. Some of the meshes enclosed by the reticulated fibers are about 0.2 mm. in diameter. Distinct black dots near the median part of the frond number 5 in 0.5 mm. Some of the hair-like fibers present similar series of dots of smaller size, regarded as denticulations on the sides of these fibers. The larger dots within the flat area of the frond may have served as points of attachment of some of the hair-like fibers.

The frond in the lower right-hand corner of specimen 7 has a rachis-like film 0.5 mm. wide. The black dots belonging to the reticulating fibers number 5 in 0.5 mm. Those belonging to the hair-like fibers number 7 in the same distance.

In specimen 13 the main rachis-like film is 0.7 mm. wide, the corresponding parts of the lateral lobes are 0.4 mm. in width. The specimen 14 has a main rachis-like film 0.4 mm. wide, the lateral median films being 0.3 mm. in width. The frond apparently was about 0.1 mm. thick. Seven black dots occur in a length of 0.5 mm. on the surface of the frond, but these dots are as fine as those belonging to the hair-like fibers. In specimen 15 the width of the rachis-like film is 0.5 mm. In specimen 16 its width is also about 0.5 mm. The corresponding lateral films are 0.3 mm. wide. Black dots tend to occur locally in diagonally intersecting series. Between 6 and 7 dots occur in a length of 1 mm., apparently serving as points of attachment for the hair-like fibers. In specimen 17 the main rachis-like film is from 0.7 to 0.8 mm. wide; the corresponding lateral structures are 0.4 mm. wide. Near the margin of the frond 4 to 5 black dots occur in a length of 0.5 mm.

In specimen 18A the rachis-like film is 0.3 mm. wide. The substance of the frond evidently consists of something more than

a thin carbonaceous film, the reticulating fibers being distributed through a visible thickness of the matrix, though possibly scarcely a 0.1 mm., in this dimension. The reticulation of the fibers of the frond can be recognized locally. The hair-like fibers extend 2 mm. beyond the margin of the frond. They arise apparently from black dots on its flat surface.

In specimen 19 the rachis-like film is 0.5 mm. wide. The reticulated structure of the fibers forming the body of the frond is visible. From 4 to 6 hair-like fibers occur in a width of 0.5 mm. along the margin of some of the lobes. From 6 to 7 dots may be recognized in a length of 0.5 mm. along some of these fibers.

In specimen 21A the rachis-like film, 0.5 mm. wide, is distinctly shown, and the series of dots belonging to the fibers along the margin of some of the lobes are distinctly visible. Of the larger black dots, 6 or 7 occur in 1 mm.

In specimen 25 the median rachis-like film is 0.4 mm. wide; the corresponding structures of the lateral lobes are far less distinctly outlined. The appearance of reticulation among the fibers forming the frond is strikingly shown. Some of the meshes are 0.4 mm. long and 0.2 mm. wide. On close examination many of these fibers appear to be supplied by a series of dots, varying from 5 to 7 in a length of 0.5 mm. Some of those near the margin of the frond serve as points of attachment for the hair-like fibers. At one point numerous hair-like fibers may be traced for almost 3 mm. beyond the margin of the frond. They are shown best near B as located on plate IX.

### **Buthotrephis Hall**

The genus *Buthotrephis* was founded by Hall<sup>11</sup> on *Buthotrephis tenuis* Hall, from the Trenton of New York, and not on *Buthotrephis antiquata* Hall, from the Chazy of that state. This is evident from his statement in the description of *Buthotrephis antiquata* that "In the present genus, the typical form is to be found on plate 21, fig. 1," where the genotype is erroneously

<sup>11</sup> Hall, James, Paleontology of New York, vol. 1, p. 8, 1847.

portrayed under the name *Buthotrephis gracilis*, a name previously used by Hall in 1843<sup>12</sup> for a Clinton form of New York. In the second volume of the Paleontology of New York (p. 18) Hall corrected this error and introduced the name *Buthotrephis tenuis* for this genotype.

In describing *Buthotrephis tenuis* Hall states that "A carbonaceous film is all that remains of the fossil," and also that this fossil is found "upon a shaly carbonaceous film on the limestone."

In his original description of the genus Hall defines the latter as follows: Stems subcylindric or compressed, branched; branches numerous, divaricating, leaflike; structure vesicular?

Little appears to be gained by a study of the Trenton type. In his study of two species from the Kokomo member of the Cayugan, at Kokomo, Indiana, however, Dr. David White makes some observations which may prove illuminating in connection with the structure of the genus *Leveilleites*. He describes the fronds of *Buthotrephis divaricata* White<sup>13</sup> as rugulose or minutely granulose, and marked, especially along the medial portion, by very delicate, irregularly, but more or less obliquely, arranged trichomatose or filamentose impressions. Without a central axis or strand. Vague globular bodies near or at the apices of the branches. Similarly he describes the texture of *Buthotrephis newlini* White<sup>14</sup> as slightly rugose, marked by irregular, very slender, intermingled and tangled trichomatose or filamentose elements, those near the center being coarser, often thread-like, and more or less longitudinal in their arrangement. Similar filamentose texture occurs in *Buthotrephis lesquereuxi* Grote and Pitt, from the Bertie member of the Cayugan at Buffalo, New York. Here there is an irregularly woven or cloth-like mesh.

More recently, specimens referable to *Buthotrephis lesquereuxi*

<sup>12</sup> Hall, James, Geology of New York, part 4 (fourth district), p. 69, fig. 14.

<sup>13</sup> White, David, Two new species of Algae from the upper Silurian of Indiana: U. S., Nat. Mus., Proc., vol 24, pp. 265-270, pl. 16, 1902. See also Proc. Biol. Soc. Washington, 15, 1902, p. 86.

<sup>14</sup> Idem. p. 266, pls. 17, 18.

have been studied by Dr. Rudolph Ruedemann,<sup>15</sup> and have been referred by him to the genus *Inocaulis*. Figure 4 on plate 4 of his account shows in striking manner the black dots on the surface of the frond, evidently serving as points of support of the hair-like fibers which evidently cover the entire surface of the frond, but which are seen best where projecting beyond its margins. According to Dr. Ruedemann the surface of the frond-like growth is covered with fine tubercles in some places and with fine pores in others. The tubercles are the casts of the pores, so that the entire surface of the organism appears covered with pores. The pores terminate in fine straight tubes having the dimensions of fibers, more or less perpendicular to the surface of the frond. Of the circular pores 5 occur in a length of 1 mm. The width of the hair-like tubes is 0.05 mm. The original form of the branches of the frond is regarded as having been cylindrical in form. Such fibers as appear within the fronds appear twisted together irregularly, rather than forming reticulating meshes. The structure is regarded as graptolitic, allied to *Inocaulis*, *Palaeodictyota*, *Acanthograptus*, and the like. The possibility of the fibers being chitinous, rather than carbonaceous, is indicated.

It is evident that *Leveilleites* presents structures suggestive of the Kokomo and Buffalo forms formerly referred to *Buthotrephis*. There is a possibility of their being of animal, rather than of vegetable origin. As to their affinities to the Dendrograptidae among the Dendroidea order of the graptolites, the present writer is in no position to express any opinion, not being sufficiently familiar with the latter.

***Buthotrephis creditensis* Sp. nov.**

*Plate XV A, figs. 15 A, B*

Flat fronds, known only from fragments 65 mm. long and 30 to 35 mm. wide; originally probably similar in size and shape to

<sup>15</sup> Ruedemann, Rudolph, Account of some new little-known species of fossils, mostly from the Paleozoic rocks of New York: N. Y. State Mus. Bull. 189, 1916, pp. 13-17, text fig. 4 and pl. 4, figs. 1-4.

the specimen of *Phaenopora expansa* Hall and Whitfield, illustrated in 1893,<sup>16</sup> excepting that one of the specimens has a more distinct lobation along one part of its margin. None of the specimens are dichotomously branched as in the species of *Buthotrephis* described from the Bertie member of the Cayugan in the Buffalo area of New York, or those described from the Kokomo member of the Cayugan of northern Indiana. Although to the unaided eye these fronds appear flat and continuous, under the microscope the frond appears to possess a structure consisting in part of longitudinal lines connected by cross lines, producing oblong or oval meshes, the whole somewhat resembling a *Dictyonema*. Of the more or less branching longitudinal lines there usually are from 7 to 8 in a width of 5 mm. Of the oblong or oval meshes there are about 5 or 6 in a length of 5 mm. It is impossible to determine from the material in hand how the walls of these meshes are constructed. Apparently they are built up of fibers, more or less reticulating, so as to produce narrow walls more or less vertical to the plane of the fronds, at least along that part of the walls which lies nearest the surface of the frond. The inner part of the frond appears to consist of a continuous sheet of black material, although it is possible that here the fibers are merely more closely interlaced. It is impossible to determine whether the oblong or oval meshes occur only on one side or on both sides of the frond. If they locate anything corresponding to zooecia, it has been impossible to verify this fact.

Locality and formation.—Associated in the same fragments with *Leveilleites* in the basal members of the Manitoulin dolomite, at Credit Forks, Ontario.

***Dictyonema scalariforme creditensis* Var. nov.**

*Plate IV, fig. B*

*Dictyonema scalariforme* Foerste, Bull. Sci. Lab. Denison Univ., 2, pt. 1, 1887, p. 108, pl. 8, figs. 28, 29; Geol. Surv. Ohio, Pal. 7, 1893, p. 600, pl. 27, figs. 28, 29.

<sup>16</sup> Foerste, A. F., Fossils of the Clinton group in Ohio and Indiana: Ohio Geol. Surv., vol. 7, pl. 29, 1893.

Rhabdosome originally infundibuliform, with sides diverging at angles varying in different specimens from  $45^{\circ}$  to  $75^{\circ}$ . The base of this rhabdosome tends to be pointed. Its length usually is from 25 to 30 mm. Between 12 and 15 branches occupy a width of 10 mm. The branches vary from 0.3 to almost 0.5 mm. in width, and tend to be narrower than the spaces between them. Usually the branches are almost straight. They are connected by dissepiments forming large angles (usually nearly right angles) with the branches. Seven or 8 of these dissepiments occur in a length of 5 mm. Along the greater part of their length these dissepiments are only slightly larger than 0.05 mm., but they enlarge near contact with the branches. The resulting meshes are quadrangular. The apertures of the thecae are not distinctly preserved in any specimen at hand but in several specimens the worn surfaces show rounded or elliptical outlines which are regarded as locating the thecae. Of these there are about 9 in a length of 5 mm., the number decreasing in some specimens to 8 in this distance.

Locality and formation.—In the quarry north of the deep ravine at Credit Forks, Ontario, a quarter of a mile west of the railroad station. In the basal part of the Manitoulin dolomite, a member of the Medinan.

Remarks.—In the original description of *Dictyonema scalariforme* the number of thecae was given as 13 in a length of 5 mm. Since in the Credit Forks specimens only 9 were noticed in the same distance there is a possibility that a distinct form here is represented, for which the name *Dictyonema scalariforme creditensis* is proposed.

D. A LOWER MEDINAN FAUNA BELOW THE BRASSFIELD LIMESTONE  
IN OHIO

In the quarry half a mile northeast of Centerville, Ohio, and about  $\frac{1}{3}$  of a mile northwest of the railroad station, the full section of the Brassfield limestone and of the Dayton limestone is exposed. At one point the Dayton limestone is overlain by the lower part of the argillaceous layers formerly known as the Niagara shale, and at present doubtfully referred to the Alger

shale. Beneath the Brassfield limestone there are about 4 feet of argillaceous material weathering into a gritty clay. The latter has recently been traversed by ditches, and numerous gastropoda, of strongly Ordovician aspect, have been exposed. In addition there is a species of *Ctenodonta* and of one *Spyroceras*, both of which have Ordovician affinities. The brachiopoda, on the contrary, are distinctly Silurian in character, and the same is true of one fragment of a pygidium of *Dalmanites*. The list includes the following:

1. *Schuchertella subplana brevior* Var. nov.
2. *Brachyprion*
3. *Whitfieldella* cf. *ovoides* Savage
4. *Bellerophon centervillensis* Sp. nov.
5. *Hormotoma trilineata* Sp. nov.
6. *Hormotoma centervillensis* Sp. nov.
7. *Liospira* (?) *depressum* Sp. nov.
8. *Lophospira ehlersi* Sp. nov.
9. *Lophospira* (*Ruedemannia* ?) *centervillensis* Sp. nov.
10. *Loxoceras husseyi* Sp. nov.
11. *Spyroceras microtextile* Sp. nov.
12. *Ctenodonta* cf. *simulatrix* Ulrich
13. *Dalmanites*

The specimens are not found in situ but occur intimately mixed together in the material thrown out from the ditch, and this material occurs in the original low ridges formed at the time these ditches were dug. Any effort to discover any other source is futile.

Since the Edgewood limestone in southern Illinois and eastern Missouri occurs below the Brassfield limestone of those states, the fauna of the Edgewood limestone, as described and figured by Savage<sup>17</sup> was searched for possible similar species, but with no definite success. Such genera as *Schuchertella*, *Brachyprion*, *Whitfieldella*, *Bellerophon*, *Hormotoma*, *Liospira*, *Lophospira*, *Ctenodonta*, and *Dalmanites* are represented in the Edgewood limestone, and although none of the species from the Center-

<sup>17</sup> Savage, T. E., Stratigraphy and paleontology of the Alexandrian series in Illinois and Missouri: Illinois State Geol. Surv. Bull. 23, 1913.

ville quarry can be proved identical with those found in the Edgewood limestone, the affinity of these specimens from the lower argillaceous strata in the Centerville quarry appears to be nearer those of the Edgewood formation than those of any other formation so far described. Additional material is needed to confirm such a correlation.

Back of a house on the west side of the road following Beasley fork southward from West Union, Ohio, there is an exposure of Belfast rock, beneath the typical Brassfield. The upper layer, 1 foot thick, is the typical Belfast. Below this is more shaly rock, containing *Enterolasma caliculum*. About 4 feet beneath the typical Belfast there is a thin argillaceous rock layer containing the Rhynchonelloid here identified as *Rhynchotrema thebesensis* Foerste, and a form resembling *Hormotoma trilineata*, Foerste, but smaller in size. Prof. W. H. Shideler, who was the first to recognize the Silurian age of these strata, found also a small form of *Whitfieldella* at this horizon.

*Rhynchotrema thebesensis* was found by Prof. Shideler also on the E. P. Smalley farm, about 2 miles south of Lawshe, in Adams county, where a small stream flows into Brush creek from the east. Here the Belfast bed is  $5\frac{1}{2}$  feet thick.

At the Whippoorwill chapel,  $2\frac{1}{2}$  miles northeast of West Union, the typical massive Belfast bed contains *Platystrophia daytonensis* Foerste and several annulated specimens of Orthoceroids, possibly *Dawsonoceras*. In the overlying thin-bedded argillaceous strata the same species occur as are found in the immediately overlying part of the Brassfield limestone. These thin-bedded argillaceous strata at the base of the Brassfield limestone, and carrying a Brassfield fauna, are especially common in the northwestern quarter of Adams county, Ohio, between Winchester, Graces Run, Seamon, and northward.

These argillaceous strata carrying the Brassfield fauna, whether these strata be thin-bedded or thicker-bedded, are distinct from the lower argillaceous strata carrying the fauna listed from the base of the Centerville quarry, the Beasley Fork locality, and the locality 2 miles south of Lawshe, on the E. P. Smalley farm. The former are clearly of Brassfield age. The

latter appear to belong to a distinctly lower horizon, possibly corresponding to the Edgewood of western Illinois and eastern Missouri.

**Schuchertella subplana brevior** Var. nov.

*Plate XIV, fig. 13*

Width of shell at hinge-line 29 mm.; length 18 mm. Pedicel valve with a maximum convexity of 1.5 mm. at a distance of 3 mm. from the hinge-line, flattening out toward both the lateral and anterior margins. Radiating striae alternating in size; about 8 of the more prominent striae occupy a width of 5 mm. along the anterior margin of shell. Brachial valve more evenly convex, with the maximum convexity at about two-fifths of the length of the shell from the hinge-line.

Locality and formation.—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio; in the argillaceous strata immediately beneath the Brassfield limestone.

Remarks.—In typical *Schuchertella subplana* (Conrad) the ratio of the length to the breadth usually varies from 75 to 90 per cent, while the form here described has a ratio of only 62 per cent.<sup>18</sup>

The Waldron form, also known under the name *Schuchertella subplana*, is as short as the Centerville form, but the radiating striae are coarser. It may be known as *Schuchertella subplana waldronensis* Var. nov.

**Brachyprion** sp.

*Plate XIV, fig. 12*

Shell 25 mm. in width, enlarging to 30 mm. along the hinge-line, owing to the acute extension of the postero-lateral angles. Length 21.5 mm. Only the interior of a valve is at hand and this is assumed to be the pedicel valve. The hinge-area is 1 mm. in height at the beak. On the inner surface of this valve a strong median striation extends from a short distance anterior to the beak forward to a point about half-way

<sup>18</sup> Hall, James, Paleontology of New York: vol. 2, 1852, pl. 53.

between the beak and the anterior margin of the shell. Judging from the concavity of the inner side of this valve, the maximum convexity of its exterior was about 9 mm. from the hinge-area, and it equalled about 3 mm. From this point the convexity continued quite evenly as far as the lateral and anterior margins of the valve. The radiating striae on the outer surface of the shell were very fine and even, and numbered about 10 to 12 in a width of 3 mm.

Locality and formation.—Quarry  $\frac{1}{2}$  a mile northeast of Centerville, Ohio; in the argillaceous strata immediately beneath the Brassfield limestone.

Remarks.—*Brachyprion stropheodontoides* Savage is figured and described as rather strongly convex in the median portion of the ventral valve, and as most strongly convex in its umbonal region. There is no corresponding accentuation of the convexity of this valve in its median parts in the Centerville species here described.

#### **Whitfieldella cf. ovoides** Savage

*Plate XIV, fig. 14*

*Whitfieldella ovoides* Savage, Bull. Geol. Surv. Illinois, 23, 1913, p. 90, pl. 5, figs. 13-15; pl. 7, fig. 13.

Shell 16.5 mm. long, about 14 mm. wide, and estimated to have been about 10 mm. thick. The pedicel valve is considerably deeper than the brachial valve, and arches strongly over the latter at its beak. The shell tends to be broadest at its posterolateral margins, about 7 mm. anterior to the beak of the pedicel valve. Anteriorly the lateral outlines converge. The anterior margin is rounded. The median part of the pedicel valve is grooved rather narrowly. Casts of the interior of the pedicel valve are fairly common, and exhibit casts of the cavity beneath the beak enclosed by the convergent dental lamellae, and casts of the impressions left by the diductor scars. The latter are striated or ridged longitudinally. The surface of both valves is rather strongly marked in a concentric manner by striae or ridges indicating successive stages of growth. Possibly these

are not so strongly marked on other specimens as on the single one at hand which shows the surface features.

Locality and formation.—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio; in the argillaceous strata immediately beneath the Brassfield limestone.

Remarks.—These Centerville specimens bear some resemblance to *Whitfieldella ovoides* Savage, from the Edgewood limestone of Illinois and Missouri and the Channahon limestone of Illinois. Better specimens are needed to make strict comparison possible.

A similar form, 13 mm. in length, was found by Professor W. H. Shideler about 4 feet below the base of the typical Belfast bed exposed 2 miles south of West Union, on the Beasley Fork road, in strata containing *Hormotoma* sp., and *Rhynchotreta thebesensis*.

### ***Rhynchotreta thebesensis* Foerste**

#### *Plate XIV, fig. 15*

*Rhynchotreta thebesensis* Foerste, Bull. Sci. Lab. Denison Univ., 14, 1909, p. 94, pl. 4, figs. 66 A-C; Savage, Bull. Geol. Surv. Illinois, 23, 1913, p. 80, pl. 4, figs. 19-20.

Valve, regarded as brachial, 16 mm. long, 16 mm. wide, with a convexity of 4 mm. Ornamented by 10 coarse, radiating plications which at the anterior margin of the shell are strongly angular and 1 mm. in height. In the absence of the pedicel valve, and without any knowledge as to the structure of the inner surface of the valve at hand, it is impossible to determine with confidence the generic relations of this valve; but, in its size and general appearance, it resembles the shell described from the Edgewood formation of southern Illinois, and eastern Missouri, under the name *Rhynchotreta thebesensis*.

Locality and formation.—Found by Professor W. H. Shideler on the E. P. Smalley farm, 2 miles south of Lawshe, on a small creek flowing into Brush creek from the east. A similar specimen was found by him also two miles south of West Union, along the Beasley Fork road, beneath a typical exposure of Belfast rock about 4 feet. The Belfast bed here is 1 foot thick.

***Bellerophon centervillensis* Sp. nov.***Plate XIV, fig. 20*

Shell attaining a diameter of 20 mm. in a direction across the umbilicus; but most specimens vary between 12 and 15 mm. No specimen retaining the entire width of the shell at its flaring aperture is at hand, but from such fragments as are preserved it is estimated that this aperture is at least as wide as the diameter of the shell across its umbilicus. The general cross-section of the last volution is almost evenly convex, with only a faint tendency toward angularity toward the slit-band. The slit-band varies in width from about 0.4 mm. in specimens of average size to 0.6 mm. in a few of the larger specimens. The slit-band is borne on the crest of a median carina whose elevation usually is barely  $\frac{1}{3}$  mm. above the general convexity of the shell, and never exceeds 0.5 mm. The lateral walls of this carina usually rise rather abruptly. The umbilicus is small, but distinct, varying in size between that shown by *Bellerophon troosti* and its variety *burginensis*.<sup>19</sup> Along the side of the shell, the reflexed lateral margin of the posterior part of the aperture terminates against the posterior wall of the umbilicus, and there is no evidence of a strong posterior reflexion of the posterior or inner lip of the aperture along the median part of the shell. It is possible, therefore, to see the carina and the transverse surface striae along that part of the last volution which usually, in species of *Bellerophon*, is covered by the reflexed inner lip of this aperture. The surface of the shell is covered by very fine transverse striae, strongly reflexed both laterally and toward the carina, very much as in *Bellerophon recurvus* Ulrich.<sup>20</sup>

Locality and formation.—Quarry  $\frac{1}{2}$  mile northeast of Center-ville, Ohio, in the argillaceous strata immediately beneath the Brassfield limestone.

Remarks.—*Bellerophon centervillensis* has a decidedly Ordovician aspect. From *Bellerophon consimilis* Savage it differs in

<sup>19</sup> Ulrich, E. O., and Scofield, W. H., The Lower Silurian Gastropoda of Minnesota: Minn. Geol. and Nat. Hist. Surv., Pal., vol. 3, 1897, pl. 64, figs. 1, 4, 6.

<sup>20</sup> Idem., pl. 64, figs. 12, 13.

being distinctly less angular along the median part of the shell, resulting in a less triangular cross-section. Unfortunately the surface striae of the Edgewood species are unknown.

**Hormotoma trilineata** Sp. nov.

*Plate XV, Fig. 6*

Spire attaining a length of 32 mm., and a width of 14 mm.; apical angle usually between  $28^{\circ}$  and  $33^{\circ}$ . The number of volutions usually is 10 or 11. The sutures form an angle of about  $75^{\circ}$  with the vertical axis of the shell. The slit-band is peripheral in position; its width varies from 0.6 to 1 mm. The upper margin of the slit-band tends to be at mid-height of the volution and to form its most prominent part, while the lower margin of this band lies along the lower slope of the volution, slightly closer to the axial part of the shell. The general form of the volutions varies considerably in different specimens. Usually there is a tendency toward angularity, the margins of the slit-band being elevated slightly above the general convexity of the volutions, sometimes with a faint concave curvature of the shell both immediately above and below the band. In some specimens the concave curvature immediately above the band is quite distinct and broad. In that case there may be a faint revolving angulation about 1.5 mm. above the slit-band. Above this angulation there may be a slight flattening of the general convexity of the volutions. At the sutures the surface curves abruptly inward. On the lower slope of the last volution, at a distance of 2.5 mm. from the slit-band, there may be a second faint angulation, usually stronger than the one described first. In by far the greater number of specimens the general convexity of the volutions tends to be angulated on approaching the slit-band, and the upper half of the volutions tends to be slightly conical in slope.

Along the upper part of the shell the slit-band usually is trilineate, two very narrow sharp lines forming the lateral borders, and a broader line occupying the median line, or a position slightly above the median line of the band. The trilineate character

of the band can be detected where the diameter of the shell is only 1.5 mm. On the last one or two volutions the median line frequently becomes obsolete, and the area of the slit-band is relatively flat. Not infrequently the slit-band is strongly convex across its entire width, the bordering striae are obsolete or have weathered away, and the general resemblance of the shell is similar to that of *Lophospira producta* Ulrich or *Lophospira bowdeni* (Safford). In most of these cases the resemblance is striking only along the last 3 or 4 volutions, and the earlier volutions show the trilineate character of the slit-band with varying degrees of distinctness.

The course of the transverse striae is the same as that indicated by Ulrich<sup>21</sup> in his figures of *Hormotoma*. The lunulae traversing the slit-band transversely are well shown. The apertures, as far as preserved, are similar.

Locality and Formation.—Found in the large stone quarry half a mile northeast of Centerville Ohio, in the argillaceous strata immediately underlying the Brassfield limestone.

Remarks.—The relationship of this species appears to be with *Hormotoma gracilis* Hall and *Hormotoma subangulata* Ulrich and Scofield, rather than with *Hormotoma salteri* Ulrich. At any rate, the surface of the volutions does not curve concavely upward on approaching the sutures above them.

More than a thousand specimens were examined. This accounts for the numerous variations, some of which have been noted above. Some variations are represented only by a few specimens. For instance, in some cases the angulations above and below the slit-band are very distinct, and there may be even a second angulation present above this band. Individuals with an apical angle of 37° to 40°, and with only 8 or 9 volutions, also are relatively rare, but more than 20 specimens were noted. (Plate XV, fig. 4.)

In one specimen with an apical angle of 35 degrees, 9.8 mm. wide at the base, 8 volutions are present, and 2 or 3 belong to the apical part, which is missing. The volutions in this case appear

<sup>21</sup> Idem., pl. 70.

low and crowded, resembling those of *Coelocaulus oehlerti* Ulrich<sup>22</sup> in their crowded conditions, but the spire is much shorter. (Plate XV, fig. 5.)

In a few specimens the slit-band is traversed by 3 revolving striae or lines of elevation, the two lateral ones lying closer to the median striation than to the striae forming the lateral margins of this band.

A similar form, but only 6 mm. in length and with 5 or 6 volutions, was found by Professor W. H. Shideler of Miami University at the exposure of the Belfast bed 2 miles south of West Union, on the Beasley Fork road. The typical Belfast bed here is 1 foot thick, and the specimens of *Hormotoma* are common about 4 feet beneath.

No Silurian species of *Hormotoma* with such a strongly Ordovician facies as that presented by the specimens here described are known. *Loxonema subulata* Conrad may be a *Hormotoma*, but it presents an aspect quite different from that of the Centerville specimens.

***Hormotoma centervillensis* Sp. nov.**

*Plate XV, fig. 7*

Spire with an apical angle of about 20° and with sutures forming an angle of about 70° with the vertical axis of the shell. The base of the shell attains a maximum diameter of 11 mm. Five volutions occur in a length of 26.5 mm., and it is estimated that the original length of the shell equalled about 36 mm., and that within this length there were 10 or 11 volutions.

Compared with *Hormotoma trilineata* the volutions are more oblique and more elongate. No tendency toward angulation of the volutions along its periphery, where the slit-band is located, is noticed. The surface here is evenly convex. The margins of the slit-band are indicated by relatively faint, and very narrow lines. The area of the band itself is flat, and shows no evidence of trilineation.

<sup>22</sup> Idem., pl. 70, figs. 61, 62.

In one specimen the surface of the shell curves upward on approaching the suture above, somewhat as in *Hormotoma salteri canadensis* Ulrich,<sup>23</sup> but in the remainder this feature is not noted.

This form may eventually prove to be only one of the many variants of *Hormotoma trilineata*, but at present it appears sufficiently distinct to warrant a different name.

Locality and horizon.—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio; in the argillaceous beds immediately beneath the Brassfield formation.

Remarks.—Compared with *Hormotoma subulata* (Conrad) the volutions of this species are relatively shorter. It is similar in size and in the number of volutions to *Hormotoma tenera* Savage, but the surface features of the latter are not known, so that exact comparison is impossible.

***Liospira* (?) *depressum* Sp. nov.**

*Plate XIV, fig. 16*

Shells attaining a height of 5.5 mm. and a maximum diameter of 13 mm. Spire very depressed. Omitting the last half of the last volution, the height of the apical part of the spire over the remainder of the shell equals slightly more than 0.5 mm.; above the aperture it rises about 2 mm., most of this elevation being due to the downward curvature of the last half of the last volution. There are 4 volutions, enlarging to a width of slightly more than 4 mm. at the aperture of a shell 5.5 mm. in diameter. Toward the apical end the cross-sections of the volutions are more nearly circular, but along the last volution the depression of the shell becomes increasingly obvious, and at the same time there is a moderate obliquity of the upper surface of this volution, especially toward the aperture. The umbilicus is about 2 mm. in diameter. Along the last half of the last volution this umbilicus is bordered by a callous deposit along the inner margin of this part of the volution. This deposit varies from 1 to 1.2

<sup>23</sup> Idem., pl. 70, fig. 48.

mm. in width, has a thickness of about 0.5 mm., is distinctly outlined along its convexly curved margin, and presents a steep slope on its concavely curved side, facing the umbilicus. No trace of surface markings is visible. Therefore it is impossible to determine the generic relations of this species. The fact that the callous deposit is strongly margined along its exterior border suggests that this shell may be generically distinct from *Liospira*.

Locality and formation.—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio, in the argillaceous strata immediately beneath the Brassfield limestone. Possibly a *Pycnomphalus*.

***Lophospira ehlersi* Sp. nov.**

*Plate XIV fig. 17*

Shell 17.5 mm. in height, with a maximum width of 15.5 mm., and an apical angle of about  $80^\circ$ . At the aperture the last volution has an elevation of 10 mm. There are 5 or 6 volutions, the apical one rarely being preserved distinctly. General outline similar to that of *Lophospira peracuta* Ulrich and Scofield<sup>24</sup> but with a much lower spire, somewhat as in *Lophospira tropidophora* Meek. The upper volutions expose only their upper slopes and the peripheral angle, but the second last volution exposes an increasing amount of its lower slope, so that near the aperture fully 2 mm. intervene between the peripheral angle of the second last volution and the suture beneath. The peripheral angle is more or less acute, the degree of acuteness usually being greater along the last volution. The slit-band is located on the peripheral angle. At the aperture its width is about 1 mm. or slightly more. Its upper and lower margins are defined distinctly by very fine, sharp lines. The entire width of the band is raised into an angular ridge, whose upper and lower faces form an angle of about  $60^\circ$ . The upper face of the slit-band slopes at about the same angle as the upper face of the volution, and the lower face of the band slopes at an angle similar to that of the lower face of the volution, the crest of the ridge formed by the band being directed upward and outward.

<sup>24</sup> Idem., pl. 73.

Near the band the upper surface of the last volution is concavely curved, and a similar concave curve marks the lower surface of this volution, at a distance of 2 mm. from the crest of the carina formed by the band. In general, the lower surface of this last volution has an outline similar to that of *Lophospira peracuta*, and the transverse striae follow a similar course, both above and below the band. A narrow umbilical opening is left between the inner lip of the aperture and the remainder of the last volution.

Locality and formation.—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio, in the argillaceous strata immediately beneath the Brassfield limestone.

Remarks.—*Lophospira ehlersi* has a distinctly Ordovician aspect. Compared with *Lophospira thebesensis* the spire is taller, and the peripheral angle is much more acute.

Named in honor of Prof. George M. Ehlers, one of the geologists active in collecting the gasteropoda of the lower strata in the Centerville quarry.

***Lophospira* (Ruedemannia?) centervillensis Sp. nov.**

*Plate XIV, fig. 18*

Shell 1.2 mm. in height, 11 mm. in maximum width, with the last volution occupying a height of 7 mm. near its aperture. The apical angle is about  $87^\circ$ . There are 6 volutions, of which the apical one scarcely ever is distinctly preserved. The slit-band is located at the angular peripheral margin, about 0.75 mm. beneath the level of the suture limiting the last volution. Above this band the surface of the volution rises only moderately toward the suture, while immediately below the band the outline of the volution is either vertical or curves slightly outward before curving inward toward the umbilical parts of the shell. In general the outline of this shell is similar to that of *Lophospira sumnerensis* (Safford), but with the peripheral angle located farther up on the volutions, the angulation of the spire resembling that of *Lophospira trochonemoides* Ulrich, but without any angulation along the lower part of the last volution, where the surface curves toward the umbilicus.

Near the aperture the width of the upper flattened surface of the last volution is nearly 4 mm. Approximately half-way between the peripheral angle and the suture there is a prominent revolving rib, the area between this rib and the peripheral angle being distinctly concave. A similar concave area, 2 mm. in height, extends from the peripheral angle downward. Beneath this area there is a series of revolving ridges of which the upper 5 are distinct and occupy a total height of 2.3 mm. Beneath this level 4 or 5 much fainter revolving lines are seen, occupying about the same space measured along the vertical curvature of volution.

The slit-band is 0.7 mm. wide near the aperture; it is bordered by very fine, sharp lines, and its entire width is raised so as to form an angle of about  $90^\circ$  along the median line, the apex of this angle being rounded.

Along the flattened slope above the peripheral angle the transverse striae are very fine and curve strongly back toward the slit-band. Below the peripheral angle the transverse striae are nearly vertical, except within the groove immediately below this angle, where the striae curve distinctly back toward the slit-band.

A narrow umbilical opening remains between the inner margin of the aperture and the remainder of the lower face of the last volution.

Locality and formation.—From the argillaceous layers immediately below the Brassfield limestone at the quarry half a mile northeast of Centerville, Ohio.

Remarks.—This species is regarded as closely related to *Lophospira inexpectans* (Hall and Whitfield), but the striation of the latter is much finer and more abundant in a revolving direction.

*Poleumita bellasculptilis* Savage has an angular carina separating the upper slope of the volutions from their middle and basal portions. Along the last volution this upper slope is nearly flat and is marked by 3 revolving ridges of which only the middle one persists in the two uppermost volutions. Below the carina there are 12 to 15 revolving ridges. The upper volutions grad-

ually become more rounded, the more apical volutions being nearly circular in cross-section. There is some resemblance here between the mature form of *Poleumita bellasculptilis* and *Lophospira centervillensis*, but since their early stages are entirely different, according to the description presented by Salvage, it is not likely that they are related generically.

***Loxoceras husseyi* Sp. nov.**

*Plate XV, figs. 3 A-D*

Conch in its present condition more or less elliptical in cross-section; 15 mm. wide laterally and 11 mm. in diameter dorso-ventrally at the larger end of one fragment of a phragmacone. At the smaller end of this fragment, 30 mm. distant, the corresponding diameters are 9.5 and 8.5 mm. Originally the cross-section probably was circular, or nearly so. Apical angle usually about  $10^{\circ}$ , equalling  $12^{\circ}$  or  $13^{\circ}$  in several specimens. Nine camerae occur in this length of 30 mm. At the smaller end of the specimen there are about 3 camerae in a length equal to the lateral diameter at the top of the series being counted. Farther up this number changes to 3.7 camerae in a corresponding length.

The sutures of the septa are directly transverse. The concavity of the septa is not well shown except at the smaller ends of specimens, but it is estimated to have been about 4 or 5 mm. where the diameter is 12 to 15 mm. Location of siphuncle central, or nearly so. Segments of siphuncle oblong-elliptical, or slightly narrower below so as to be slightly fusiform in outline; 2.5 to 3 mm. wide in specimens in which these segments are 3.5 mm. in length. Septal necks short, from 0.25 to  $\frac{1}{3}$  mm. in length.

Surface smooth. In a considerable number of specimens indistinguishable in any other respect from the smooth forms, the surface of the shell is covered by numerous very fine vertical striae varying from 7 to 13 in number in various individuals. Provisionally these striae are regarded as due to the structure of the interior of the shell, the striae appearing after a certain amount of weathering has taken place.

Locality and formation.—Quarry half a mile northeast of Centerville, Ohio, in the argillaceous strata immediately beneath the Brassfield limestone.

Named in honor of Dr. R. C. Hussey of Michigan University.

**Spyroceras microtextile** Sp. nov.

*Plate XV, fig. 2*

Fragments of phragmacones 8 to 9 mm. in diameter, very slowly enlarging. At present elliptical in cross-section, formerly probably circular, or nearly so. Distinctly annulated, 5 annulations occurring in a length equal to the diameter of the conch at the point where the annulations are counted. In a specimen in which the total length of one of the annulations together with that of the groove above is 2 mm., the annulation occupies a length of almost 0.8 mm., the groove being 1.2 mm. in length. The surface of the shell is ornamented by very fine vertical and transverse lines, of which the former are detected more readily. Of the vertical striae there are 12 in a width of 1 mm.; of the transverse striae there are about 10 to 12 in a length of 1 mm., their number varying apparently more than in the case of the vertical striae.

Locality and formation.—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio, in the argillaceous strata immediately beneath the Brassfield limestone.

Remarks.—Judging from the description of *Orthoceras textile* Hall, the Centerville species is closely similar in ornamentation, but the annulations are relatively more numerous. Unfortunately, the type of *Orthoceras textile* is lost, so that it is impossible to make closer comparisons.

**Ctenodonta** cf. **simulatrix** Ulrich

*Plate XIV, fig. 19*

Complete shells about 8 mm. in length, with outlines similar to those of *Ctenodonta simulatrix* Ulrich, from the upper part of the Richmond near Spring Valley, Minnesota. However, nothing is known of its hinge teeth.

*Locality and Formation.* Quarry half a mile northeast of Centerville, Ohio; in argillaceous strata immediately beneath the Brassfield limestone.

**Dalmanites** sp.

*Plate XIV, fig. 10*

Fragment of the right side of a pygidium, with 9 pleural ribs, each traversed lengthwise by a median groove. For a width of about 1.5 mm. the margin of the pygidium is smooth, and unmarked by pleural ribs. The pygidium probably was 20 mm. in length, exclusive of any posterior spine, if a spine was present.

*Locality and formation.*—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio; in argillaceous strata immediately beneath the Brassfield limestone.

*Remarks.*—This Centerville fragment differs from *Dalmanites danai* in having the anterior part of the pleural lobes of the pygidium more directly transverse, and the pleural ribs less strongly curved backward at mid-length of the pygidium. Moreover, the marginal part is relatively broad, flat, and free from markings by the terminations of the pleural ribs.

E. THE BRACHIOPODA OF THE BRASSFIELD LIMESTONE OF OHIO

The following is a revision of the list of brachiopoda found in the Brassfield limestone published in 1893.<sup>25</sup>

- Crania dubia Foerste
- Crania clintonensis (Foerste)
- Plectambonites transversalis (Wahlenberg)
- Plectambonites prolongatus (Foerste)
- Leptaena rhomboidalis Wilckens
- Leptaena centervillensis Foerste. Sp. nov.
- Strophonella hanoverensis (Foerste)
- Strophonella daytonensis Foerste
- Schuchertella daytonensis Foerste Sp. nov.
- Orthis euorthis Foerste (=militaris Foerste)

<sup>25</sup> Foerste, A. F., Fossils of the Clinton group in Ohio and Indiana: Ohio Geol. Surv., vol. 7, 1893, p. 597.

*Orthis dinorthis* Foerste  
*Orthis fissiplicata* Foerste  
*Hebertella fausta* (Foerste)  
*Hebertella fausta squamosa* (Foerste)  
*Hebertella daytonensis* (Foerste)  
*Platystrophia daytonensis* (Foerste)  
*Platystrophia reversata* (Foerste)  
*Dalmanella parva* (Foerste)  
*Dalmanella* cf. *eugeniensis* Williams  
*Rhipidomella hybrida* (Sowerby)  
*Triplecia orton* Meek  
*Platyerella manniensis* Foerste  
*Whitfieldella* cf. *catractensis* Williams  
*Atrypa* cf. *marginalis* (Dalman)  
*Atrypa marginalis multistriata* Foerste  
*Atrypa laticorrugata* Foerste  
*Camarotoechia* (*Stegerhynchus*) *scobina* (Meek)  
*Camarotoechia convexa* (Foerste)  
*Parastrophia sparsiplicata* (Foerste)  
*Stricklandinia triplesiana* Foerste

***Leptaena centervillensis* Sp. nov.**

*Plate XIV, fig. 11*

Pedicle valve 30 mm. long, 28 mm. wide at mid-length, 33 mm. wide along the hinge-line, the postero-lateral angles being acute. Valve moderately convex for a distance of 25 mm. anterior to the beak, and then rapidly descending toward the anterior margin for a nearly vertical distance of 15 mm. The more moderately convex part of the valve is concentrically wrinkled as far forward as 23 mm. anterior to the beak. The number of the wrinkles varies from 11 to 16 in different specimens. The wrinkles are of approximately equal size anteriorly, becoming smaller and less elevated toward the beak. About 18 mm. anterior to the beak some specimens have a rather faint tendency toward a concentric downward curvature of the shell. The radiating striae are numerous, approximately of the same size, and number about 18 in a width of 5 mm. along the anterior slope of the shell.

The muscular scar in the interior of the pedicel valve is about 15 mm. long and 12 mm. broad. Its postero-lateral margins diverge at an angle of  $80^{\circ}$ . Along the anterior half of the scar the lateral margins are approximately parallel or converge but moderately. The lateral thirds of the anterior margin are distinctly limited, but the median third is at the level of the general surface of the interior of the valve. The lateral margins rise for a height of 0.5 mm. The adductor scars extend 12 mm. anterior to the beak, the antero-lateral parts of the muscular area extending 3 mm. farther. The total space between the valves of the complete shell at its geniculation is scarcely 5 mm.

Locality and formation.—Quarry  $\frac{1}{2}$  mile northeast of Centerville, Ohio; in the upper part of the Brassfield limestone. Common.

Remarks.—Forms similar to those of typical *Leptaena rhomboidalis* are not uncommon in Brassfield strata, but the form here described is much larger, more elongate, and less abruptly geniculate anteriorly. The body of the pedicel valve is more convex, and the anterior wrinkle is not abruptly limited posteriorly.

### *Strophonella hanoverensis* (Foerste)

*Strophomena hanoverensis* Foerste, Proc. Boston Soc. Nat. Hist., 24, 1890, p. 301, pl. 6, fig. 1.

*Strophomena* (*Orthothetes*) *hanoverensis* Foerste, Geol. Surv. Ohio, 7, 1895, p. 567, pl. 27, fig. 34; pl. 31, fig. 1.

In the original description of this species it is stated that the ventral valve is convex, but that the part near the beak is flattened or even contains a very slight median depression of very short length. This depression is indicated by the upper part of the outline accompanying the figure of this supposed ventral valve. This outline is repeated in volume 7 of the Geological survey of Ohio, cited above. It is evident from this description and figure that the supposed ventral valve is in reality the brachial valve, and that the species is a true *Strophonella*.

**Strophonella daytonensis** Foerste

*Strophomena patenta* Hall and Whitfield, Geol. Surv. Ohio, Pal. 2, 1875, p. 115, pl. 5, fig. 10.

*Strophonella daytonensis* Foerste, Amer. Jour. Sci., 4th ser., 18, 1904, p. 339.

The form figured by Hall and Whitfield is the type of *Strophonella daytonensis*. It is not uncommon in the Brassfield limestone of Ohio, and occurs also in Indiana and Kentucky. Figs. 35, 36, and 37 on plate 8 of volume 2, of the Bulletin Sci. Lab. Denison Univ., 1887, and of plate 27 of volume 7 of the Geology of Ohio, 1895, may represent young individuals of this species.

**Schuchertella daytonensis** Sp. nov.

*Streptorhynchus tenuis* Foerste, Bull. Sci. Lab. Denison Univ., 2, 1887, p. 105, pl. 8, figs. 31, 32, 38.

*Strophomena* (*Orthothetes*) *tenuis* Foerste, Geol. Surv. Ohio, 7, 1895, p. 568, pl. 27, figs. 31, 32, 38.

Compared with typical *tenuis* (Hall), from the Waldron of Indiana, *daytonensis* is narrower and has radiating striae more nearly equal in size. Figure 32 on the plates cited above is the type.

**Orthis euorthis** Foerste

*Orthis calligramma* var. *euorthis* Foerste, Geol. Surv. Ohio, 7, 1895, p. 572, pl. 25, figs. 12 a, b.

The name *euorthis* appears in the description of the plate cited above, and figure 12 on this plate represents the type of the species.

**Orthis dinorthis** Foerste

*Orthis calligramma* var. *dinorthis* Foerste, Geol. Surv. Ohio, 7, 1895, p. 572, pl. 31, figs. 4, 5.

The name *dinorthis* appears in the description of the plate cited above, and figures 4 and 5 on this plate represent the types of the species.

***Orthis fissiplicata* Foerste**

*Orthis calligramma fissiplicata* Foerste, Geol. Surv. Ohio, 7, 1895, p. 573, pl. 37a, figs. 20, a, b.

This species is cited by Savage from the oolite member of the Edgewood limestone in eastern Missouri and western Illinois.

***Platyerella manniensis* Foerste**

*Platyerella manniensis* Foerste, Bull. Sci. Lab. Denison Univ., 14, 1909, p. 70, pl. 1, fig. 1A-D.

*Pentamerella?* *manniensis* Savage, Bull. 23, Geol. Surv. Illinois, Stratigraphy and Paleontology of the Alexandrian Series in Illinois and Missouri, pp. 28-36 of reprint.

*Platyerella manniensis* Foerste, Bull. Denison Univ., 19, 1920, p. 223, pl. 23, figs. 5 A-H.

This species has been found at the base of the Brassfield limestone in the quarry immediately north of Lawshe, in Adams county, Ohio. In the Alexandrian strata of Missouri and Illinois it occurs immediately beneath those strata which contain a typical Brassfield fauna. The Brassfield horizon, according to Savage, cited above, is 34 feet thick, and the underlying *Platyerella manniensis* horizon is  $1\frac{1}{2}$  feet thick. *Spirifer radialis* is found in strata overlying the typical Brassfield.

In Missouri and Illinois, the *Platyerella manniensis* horizon is underlain, in descending order, by the Essex, Edgewood, and Girardeau limestones. The argillaceous strata immediately beneath the Brassfield limestone in the quarry half a mile northeast of Centerville, Ohio, appear to belong to equivalents of either the Essex or Edgewood limestone.

***Whitfieldella* cf. *cataractensis* Williams**

*Meristella umbonata* Foerste, Bull. Sci. Lab. Denison Univ., 1, 1885, p. 88, pl. 13, fig. 2 a, b; Geol. Surv. Ohio, 7, 1895, p. 590, pl. 25, fig. 2 a, b.

The Brassfield specimens described and figured under the name *Meristella umbonata* undoubtedly resemble the type of *Athyris umbonata* Billings externally. Internally they present

the structure of a *Whitfieldella*. Under the name *Hindella umbonata* Billings Hall and Clarke figure specimens from the same locality as *Athyris umbonata* Billings, but representing outlines closely similar to those of *Athyris prinstana* Billings, both of which had been described by Billings from the same locality and horizon on Anticosti island. Hall and Clarke made these supposed specimens of *Athyris umbonata* the type of their new genus *Hindella*. However, the Brassfield specimens appear to be distinct forms of *Whitfieldella*, so that, if Billings's species *Athyris umbonata* is identical with the form so recognized by Hall and Clarke, regarding which there is some possibility of doubt, then the term *Hindella umbonata* is not suitable for the Brassfield form, and the term *Whitfieldella umbonata* might prove misleading. Possibly the Brassfield species is closely related to *Whitfieldella cataractensis* Williams from the Manitoulin dolomite and Cabot Head shale of the Cataract formation of Ontario.

#### ***Parastrophia sparsiplicata* (Foerste)**

*Cyclospira* ? *sparsiplicata* Sp. nov., Geol. Surv. Ohio, 7, 1895, p. 593, pl. 37a, figs. 18 a, b.

The chief feature of this shell is the presence of a median fold on the more strongly convex valve, the one whose beak overtops that of the other valve. This median fold bears two plications anteriorly, and an additional plication is faintly indicated on each side of the fold. No structure of this type exists in the genotype *Cyclospira bisulcata* (Emmons). However, in *Parastrophia* the brachial valve overtops the pedicel one. There is a tendency toward the development of a median fold with an even number of plications on this valve, and lateral plications occur. Therefore, it is regarded as much more likely that the Brassfield specimen in question belongs to the genus *Parastrophia*.

## F. THE GASTEROPODA OF THE BRASSFIELD LIMESTONE OF OHIO

The following is a revision of the list of gasteropoda found in the Brassfield limestone published in 1893.<sup>26</sup>

*Bellerophon exiguus* (Foerste)  
*Bellerophon opertus* Foerste  
*Bucanella trilobata* (Conrad)  
*Bucania fiscoellostriata* (Foerste)  
*Oxydiscus youngi* (Foerste)  
*Cryptaulus filitextus* (Foerste) Gen. nov.  
*Lophospira* (*Ruedemannia* ?) *inexpectans* (Hall and Whitfield)  
*Liospira affinis* (Foerste)  
*Hormotoma subulata* (Conrad)  
*Cyclonema daytonense* Foerste  
*Cyclonema gyronemoides* Foerste. Sp. nov.  
*Cyclora alta* Foerste  
*Straparollus incarinatus* Foerste  
*Diaphorostoma daytonense* Foerste. Sp. nov.  
*Subulites directus* Foerste  
*Meekospira planilateralis* (Foerste)  
*Onychochilus abruptum* (Foerste)

***Oxydiscus youngi* (Foerste)**

*Cyrtolites Youngi* Foerste, Proc. Boston Soc. Nat. Hist., 24, 1889, p. 289, pl. 6, fig. 7; Geol. Surv. Ohio, Pal. 7, 1893, p. 549, pl. 31, figs. 7, 7a.

From the cross-section of the type of the species it is evident that the last volution enveloped the carina of the preceding volution with a heart-shaped base, as in typical *Oxydiscus*, the conch being narrow and the carina very acute.

***Cryptaulus* Gen. Nov.**

Spire low, the successive volutions rising high up on the sides of the immediately preceding volutions, and covering the slit-band of the latter entirely. The upper part of each volution

<sup>26</sup> Foerste, A. F., Fossils of the Clinton group in Ohio and Indiana: Ohio Geol. Surv., vol. 7, 1893, p. 596.

is less convex than its sides, thus assisting in the general depressed appearance of the spire. Along mid-height of the last volution is a narrow slit-band, bordered on each side by a single striation, which is distinct, though but slightly raised above the general surface of the shell. General vertical outline of the volutions rounded, without revolving ridges, striae, or grooves, excepting only the groove of the slit-band. All surface striae transverse. Umbilicus open, as far as known.

Genotype.—*Pleurotomaria filitexta* Foerste.

***Cryptaulus filitextus* (Foerste)**

*Pleurotomaria filitexta* Foerste, Geol. Surv. Ohio, Pal. VII, 1893, p. 550, pl. 37A, figs. 6a, b.

Shell 10 mm. wide, and scarcely 6 mm. high. Volutions 5, the spire rising 1.7 mm. above the surface of the last volution. Slit-band barely 0.4 mm. in width near the aperture. Here 22 transverse striae occur in a width of 2 mm. These striae curve backward along the upper surface of the last volution so as to form an angle of about 70 degrees with the slit-band until within the immediate vicinity of the latter, where the transverse striae curve more strongly backward. Along the lower side of the slit-band the transverse striae also curve backward on approaching this band.

Locality and formation.—Found at the abandoned Huffman quarry  $\frac{3}{4}$  mile southeast of the Asylum for the Insane, in the southeastern part of Dayton, Ohio, in the Brassfield limestone.

Remarks.—The general appearance of *Cryptaulus filitextus* is that of a *Helix*, but provided with a slit-band at mid-height of the last volution, the slit-band of earlier volutions being covered up successively by the later volutions. No other Silurian shell with exactly the same type of structure is known.

*Pleurotomaria aequilatera* (Wahlenberg), as figured by Lindström<sup>27</sup> is similar in its general *Helix*-like form, its open umbilicus, and the presence of a slit-band at mid-height, or only slightly above mid-height of the volutions. Figure 27 on the plate cited

<sup>27</sup> Lindström, Silurian Gastropoda of Gotland, 1881, pl. 9.

bears the greatest resemblance, but in all cases the slit-band remains exposed, immediately above the sutures.

*Pleurotomaria helicina* Lindström,<sup>28</sup> is similar in having the slit-band of earlier volutions covered up by the successively later volutions, but the slit-band is located slightly above mid-height of the volutions and there is a revolving callous thickening along the rim of the umbilicus. The shell is much more depressed. Possibly this species may prove congeneric with *Cryptaulus filitextus*.

In the genus *Trepostira* Ulrich<sup>29</sup> the slit-band also is visible only on the last volution, but the umbilicus is closed by a callous deposit. Shells of this type originated apparently as early as the Hamilton formation, where *Pleurotomaria rotalia* occurs. However, the typical forms of this genus are of Carboniferous age.

**Lophospira (Ruedemannia?) inexpectans** (Hall and Whitfield)

*Pleurotomaria inexpectans* Hall and Whitfield, Geol. Surv. Ohio, Pal. 2, 1875, p. 117, pl. 5, fig. 12.

Height 26.5 mm., greatest lateral diameter 23.5 mm., greatest height of spire 16.5 mm., apical angle 83°. Slit-band peripheral, 1.5 mm. in width near the aperture, distinctly outlined along its upper and lower margins by sharply defined revolving striations. Slit-band strongly convex transversely, its median parts rising at least  $\frac{1}{3}$  mm. above its lateral parts toward the aperture. Here, where its width is 1.5 mm., the median part of the slit-band is traversed by three revolving striae, equally spaced, 0.3 mm. apart. Of these the middle striation is traversed longitudinally by an extremely narrow groove, which can be detected only where the preservation of the shell is excellent. Along the periphery of the second-last volution, the slit-band is acutely angular instead of convex, and there is only a single revolving striation, but this is prominent and is located along the median line of the band.

<sup>28</sup> Lindström, Idem., pl. 11.

<sup>29</sup> Ulrich, E. O., and Scofield, W. H., The Lower Silurian Gastropoda of Minnesota: Minn. Geol. and Nat. Hist. Surv., Pal. vol. 3, pt. 2, 1897, p. 957.

In the last volution, the vertical outline above the slit-band is gently concave, the concave curvature being more pronounced toward the band. Below the slit-band the vertical outline is convex, with a tendency toward a concave outline within 2 mm. of the band, due chiefly to the prominence of the peripheral portion of the shell bearing this band. In the second-last volution, the slope of the shell above the slit-band is interrupted at mid-height by a very prominent revolving striation, dividing this slope into two equally concave revolving areas. Along the last volution this striation becomes less prominent and occupies a position increasingly farther up the slope, being three-fifths of the distance from the slit-band to the suture above, near the aperture. Along this part of the shell the striation in question is merely slightly more prominent than those above and below, and does not interrupt conspicuously the general concave outline between the slit-band and the suture above. Above this more prominent striation, the surface of the last volution is marked by 9 revolving striae. Beneath this more prominent striation there are 4 striae about as prominent as those above this striation, and then a fifth striation distinctly more prominent than any of the preceding four is found. The upper half of the space between the fifth striation and the slit-band is occupied by 5 much fainter striae, with a sixth faintly visible a short distance beneath. Along the second-last volution only 4 or 5 revolving striae occupy each of the two concave areas forming the visible part of this volution between the slit-band and the suture above.

Immediately below the slit-band, along the concave part of the shell, toward its aperture, the revolving striae are very faint toward the band but become increasingly stronger at a greater distance. At least 40 revolving striae occur between the slit-band and the umbilical portion of the shell. These tend to be approximately equal in size, though slight alternation in prominence is noted. In general the prominence of these striae distinctly exceeds that of most of the striae along the upper two-thirds of that part of the last volution which is above the slit-band.

Transverse or vertical striae distinct, sharply defined, and equidistant. Along the peripheral part of the last volution, near the aperture, 8 striae occur in a width of 2 mm. Three millimeters below the slit-band, the number of transverse striae increases abruptly from 8 to 13 in a width of 2 mm., and this finer striation continues as far as the umbilicus.

Along the slit-band the transverse striae curve backward so as to form an angle of  $60^\circ$  with the vertical axis; farther up they form an angle of  $80^\circ$  with this axis, and farther down their direction is at first vertical, with a backward curve on approaching the umbilical parts of the shell.

Locality and Formation.—Near the Whippoorwill school,  $3\frac{1}{2}$  miles northeast of West Union, in the oolitic iron ore at the top of the Brassfield formation.

Type.—The type specimen, used for the original description, was found in the oolitic iron ore at the top of the Brassfield limestone, on Todd Fork, nearly 3 miles north of the center of Wilmington, in Clinton county, Ohio.

Remarks.—This species is characterized by the prominent elevation of the median part of the slit-band. In this respect it resembles typical *Lophospira*. It appears to have originated from a shell similar to *Lophospira lirata* Ulrich, from the Economy and Southgate members of the Eden formation in the vicinity of Cincinnati, Ohio. It resembles the latter in the division of the slope above the slit-band into two revolving concave areas, and in the tendency toward a faint concave area immediately beneath this slit-band; it is similar also in possessing revolving striae along the lower part of the last volution. It is dissimilar in having these revolving striae much more sharply defined, much more numerous and present above as well as below the slit-band.

It would have been far better if *Pleurotomaria inexpectans*, instead of *Lophospira lirata* had been selected as a type of *Ruedemannia*, since it appears to be along this direction that *Lophospira lirata* seems to have varied.

*Pleurotomaria robusta* Lindström is similar to *Lophospira lirata*, in the features mentioned above.

In *Pleurotomaria scutulata* Lindström and *P. gradata* Lindström the median part of the slit-band is occupied not by a single striation but by two, a feature throwing these shells out of alignment with *Lophospira*. In a similar manner the concave slit-bands of *Clathrospira*, *Plethospira*, and *Seelya* throw these genera out of alignment with *Lophospira* and its subdivision *Ruedemannia*.

### ***Cyclonema daytonense* Foerste**

*Cyclonema bilix* Foerste, Proc Boston Soc. Nat. Hist. 24, 1889, p. 290, pl. 5, fig. 15; Geol. Surv. Ohio, Pal., 7, 1893 p. 551, pl. 30, fig. 15.

*Cyclonema daytonensis* Foerste, 24th Ann. Rep. Indiana Geol. Nat. Hist. Surv., 1899, p. 77; Journ. Geol., 11, 1903, p. 707.

Cf. *Cyclonema bilix* Conrad, Jour. Acad. Nat. Sci. Philadelphia, 8, 1842, p. 271, pl. 16, fig. 10.

The type of *Cyclonema daytonense* is the specimen figured from Brown's quarry, near New Carlisle, Ohio, in 1889, and again in 1893, in the reports cited above. This species is widely dispersed, and is one of the most common gasteropoda found in the Brassfield formation in Ohio, Indiana, and Kentucky. In the Brassfield limestone of western Tennessee it is found as far south as Clifton, on the Tennessee river, and it has been cited from Thebes, Illinois, and Edgewood, Missouri, from the Edgewood formation.

The species *C. bilix* was described from Richmond, Indiana, where only the Elkhorn, Whitewater, and Liberty members of the Richmond, in descending order, are exposed. The Brassfield limestone is well exposed at the falls on Elkhorn creek, 3 miles southeast of Richmond.

The forms of *Cyclonema* found in the Whitewater and Liberty members are usually erect and relatively tall. *Cyclonema bilix conica* Miller<sup>30</sup> is the extreme form of this group. It has been

<sup>30</sup> Miller, S. A., The position of the Cincinnati group in the geological column of fossiliferous rocks of North America: Cincinnati Quart. Jour. Sci., vol. 1, 1874, p. 320.

well illustrated by Meek<sup>31</sup> and Ulrich.<sup>32</sup> In the Waynesville member of the Richmond the forms are relatively broader.<sup>33</sup> In the Arnheim, and in the lower part of the Waynesville members, there is a form known as *Cyclonema fluctuatum* James<sup>34</sup> which is not only broad, but which tends to be wrinkled transversely and to be depressed along the upper third of the lower volutions.

None of these Richmond forms resembles the figure of *Cyclonema bilix* published by Conrad. The latter is not a strongly erect, conical form, but, on the contrary is low and apparently with a strongly oblique axis. Shells of this type are relatively common in the Brassfield limestone, 3 miles southeast of Richmond, while not known in the Elkhorn, Whitewater, or Liberty members of the Richmond at any locality near Richmond, Indiana.

The locality and formation assigned by Conrad to his *Cyclonema bilix* was Richmond, Indiana, in limestones of the age of the Salmon river series of New York. Conrad included in his Salmon river series not only strata now known as Lorraine but also the unfossiliferous sandstone which caps the Lorraine at the Falls of the Salmon River. This accounts for his use of the term Salmon River sandstone in his various reports, although some of the underlying beds contain relatively thin sandstone layers also. It is possible that the falls of the Elkhorn were included in the Salmon River series by Conrad, and that the type of his *Cyclonema bilix* was not a Richmond, but a Brassfield form.

No good purpose, however, would be served by resurrecting the name *Cyclonema bilix* for the Brassfield, instead of the Richmond species. The mere fact that no element of certainty attaches to its stratigraphic origin suggests that either this name

<sup>31</sup> Meek, F. B., Fossils of the Cincinnati Group: Paleontology of Ohio, vol. I, 1873, pl. 13, fig. 5 g.

<sup>32</sup> Ulrich, E. O., and Scofield, W. H., The Lower Silurian Gastropoda of Minnesota: Minn. Geol. and Nat. Hist. Surv., vol. 3, 1897, pl. 78, figs. 38-39.

<sup>33</sup> Idem: pl. 78, figs. 35, 36, 37.

<sup>34</sup> Idem: pl. 78, figs. 40, 41, 42.

should be dropped, or that Ulrich should be followed in his definite choice of a type or of a series of types from a definitely known horizon. Ulrich's three specimens of *Cyclonema bilix*<sup>35</sup> figured first under that name in the Paleontology of Minnesota, from Versailles, Indiana, and Waynesville and Clarksville, Ohio, are definitely of Richmond age, and their horizon probably was that of its Waynesville member.

*Cyclonema gyronemoides* Sp. nov.

*Cyclonema bilix varicosum* Foerste, Geol. Surv. Ohio, Pal., 7, 1893, p. 552, pl. 37A, fig. 9.

Shell with 3 or 4 volutions, rapidly enlarging, the last volution forming by far the greater part of the shell. In most of the specimens at hand the spire appears somewhat depressed, similar to the spire of *Cyclonema daytonensis* as figured in 1893.<sup>36</sup> Along the middle and upper thirds of the last volution the shell is ornamented by strong revolving ridges, usually 5 in number; revolving striae also are present, but usually these are faint, are close together, and occur on the ridges as well as on intermediate parts of the shell. Along the upper half of the lower third of the last volution there are additional faint revolving striae; along the lower half of this third, only the transverse striae usually are present.

The third revolving ridge from the top of the last volution usually is located slightly above mid-height of this volution, and the other two ridges are so placed between the third volution and the suture above that the width of the intermediate concave spaces decreases only moderately in ascending order. The fourth revolving ridge occurs at an interval considerably shorter than that above the third ridge, and is distinctly less conspicuous. The fifth revolving ridge occurs at a shorter interval than any of the preceding ridges, and is distinctly less conspicuous than the fourth ridge.

<sup>35</sup> Idem: pl. 78, figs. 35, 36, 37.

<sup>36</sup> Foerste, A. F., Fossils of the Clinton Group in Ohio and Indiana: Geol. Surv. Ohio, Pal. vol. 7, 1893, pl. 30, fig. 15.

The transverse striae are much finer and more crowded than those of *Cyclonema daytonense* Foerste,<sup>37</sup> from the same horizon and general area. Near mid-height of the last volution these striae form an angle of about 30° or 35° with the vertical axis of the shell.

Locality and formation.—Found at Todd Fork, north of Wilmington, Centerville, Dayton, Sharpsville, and east of Danville, Ohio, in the Brassfield formation.

Remarks.—The only published figure of *Cyclonema gyronemoides* is that found in volume 7 of the Geological Survey of Ohio, on plate 37A, under the name *Cyclonema bilix varicosum*. This figure was based on a series of fragments of which the largest and most important consisted chiefly of the upper part of the last whorl, including the 5 prominent revolving ridges. The basal part of the last volution and the aperture were added from other specimens. This aperture evidently is that of a *Cyclonema*, and it remains to be shown that the species here described as *Cyclonema gyronemoides* possessed this type of aperture. At the time the figure was prepared numerous specimens of this species were at hand. Those recently collected do not show the aperture. In the published figure the spire appears to be much taller than in the specimens now at hand, possibly owing to the specimen being viewed from its narrowest aspect. However, here, again, there is a possibility of the apical part of the figure having been derived from some other specimen. In the specimens now at hand the spire is relatively depressed, somewhat as in the figure of *Cyclonema daytonense* published on plate 30 of the volume cited above, under the name *Cyclonema bilix*. Under these circumstances only the upper part of the last volution of figure 9 on plate 37A of the volume cited is to be regarded as unequivocally typical of the species *Cyclonema gyronemoides*; this part includes the 5 prominent revolving ridges. The remainder of the figure may be correct, but the specimens from which it was prepared have been lost, so that the accuracy of the remainder of this composite drawing can not be verified.

<sup>37</sup> Idem: pl. 30, fig. 15.

While not common, as in case of *Cyclonema daytonense*, specimens of *Cyclonema gyronemoides* are widely distributed in the Brassfield of Ohio, and form one of its characteristic species. Apparently the latter is not a species of *Gyronema*. In that genus there is a distinct umbilicus, though small, and the inner margin of the aperture is not reflexed so as to cover this umbilicus.

***Diaphorostoma clintonense* (Foerste)**

*Platyceras* Niagarenses var. *Clintonense* Foerste, Geol. Surv. Ohio, Pal. 7, 1893, p. 554, pl. 37a, fig. 8.

The type of this species was a specimen with a very low, closely coiled spire, but with the last half of the last volution curving strongly downward. It was found in the ferruginous limestone at the top of the Clinton, just under the Onondaga shales, near Mifflintown, in Juniata county, Pennsylvania.

***Diaphorostoma daytonense* Sp. nov.**

*Platyostoma* Niagarenses Foerste, Bull. Sci. Lab. Denison Univ., 1, 1885, p. 97, pl. 13, figs. 3 a; fig. 22 a, b.

*Platyceras* (*Platyostoma*) Niagarenses Foerste; Geol. Surv. Ohio, Pal. 7, 1893, p. 553, pl. 25, figs. 3 a; figs. 22 a, b.

The Brassfield form differs from the typical Rochester shale form of *Diaphorostoma niagarenses* (Hall) in possessing a lower spire, the height of the body whorl is greater, and there is less tendency toward the production of broad revolving ridges and grooves; it does not attain as large a size, and the transverse striae are finer. Only gerontic forms present the large apertures represented by figure 22 in the plates cited above. Most specimens resemble figure 32 on these plates, but with about 2 mm. added to the lateral extent of the last volution. Specimens resembling figure 3b on these plates are very rare, and represent merely aberrant individuals. For these Brassfield forms the name *Diaphorostoma daytonense* is proposed.

***Onychochilus abruptum* (Foerste)**

*Paleopupa abrupta* Foerste, Geol. Surv. Ohio, Pal., 7, 1893, p. 556, pl. 37A, fig. 21 a, b.

The genus *Onychochilus* was proposed by Lindström in 1881, in his Silurian Gasteropoda of Gotland, three species, *Onychochilus physa*, *On. reticulatum*, and *On. cochleatum* being described by him in the order named, the latter doubtfully referred to the genus. Of these the first named, *Onychochilus physa*, here is regarded as the type.

The specific name *physa* indicates the sinistral curvature of the spire of the type species, a feature shared by all three species described by Lindström, and also by the peculiar gasteropod described by me under the generic term *Paleopupa*. The choice of the name *Paleopupa* as a generic term for a sinistral shell is unfortunate, since the Brassfield species so designated could not have been ancestral to any form of *Pupa*. Its resemblance to *Pupa* ends with its rapid apical expansion, followed by a much slower expansion along the last volution. Nothing is known of its surface ornamentation.

In *Onychochilus physa* the aperture is obliquely rounded, the lower margin being distinctly angulated. There is no trace of an umbilicus. The surface striation is transverse. In *Onychochilus reticulatum* the angulation at the base of the aperture is even more pronounced. Vertical sections show that the umbilical passage through the axial part of the shell has been closed by a callous deposit. The surface is ornamented by both transverse and revolving striae, readily seen under a lens. In both species the rate of increase in size is more even than in *Paleopupa abrupta*, and in the latter species no angulation of the base of the aperture was noted, but this part was not well preserved in the specimens studied.

Nothing appears to be known of the relationship of *Onychochilus*, and the term does not appear in Zittel-Eastman's Text-book of Paleontology.

## G. NIAGARAN FOSSILS FROM JEPHTHA KNOB, KENTUCKY

Jeptha Knob is a conspicuous elevation of land 6 miles south-east of Shelbyville, in Shelby county, Kentucky. The knob attains an elevation of about 1300 feet above sea level. Its upper levels consist of Richmond strata, but on its upper parts are found also residual fragments of Silurian strata, showing that it had once been overlain by the latter. Among the latter may be recognized a few fragments of crystalline limestone, which both lithologically and paleontologically can be identified as of Brassfield age. Most of the Silurian fragments however consist of flat pieces of chert. These pieces of chert evidently were derived from chert layers interbedded in some limestone formation. Since in the counties directly west of Shelby county, including Oldham and Jefferson counties, it is the Laurel member of the Niagaran which contains flat layers of chert in abundance, these Silurian chert fragments on Jeptha Knob are interpreted as also of Laurel age.

Both Prof. Arthur M. Miller of the University of Kentucky, and Prof. Walter H. Bucher of Cincinnati University have been very active in securing fossiliferous fragments of this Laurel chert, and both have secured fragments of a large species of *Calymene*, similar to *Calymene cedarvillensis* Foerste, but possibly belonging to a distinct species. The fauna includes

- Favosites favosus (Goldfuss)
- Lyellia thebesensis Foerste
- Pachydietya cf. bifurcata (Hall)
- Dalmanella sp., with fine radiating plications
- Dalmanella sp., with very coarse plications
- Rhipidomella hybrida (Sowerby)
- Platystrophia daytonensis (Foerste). (Plate XV A, fig. 11.)
- Schuchertella sp. (Plate XV A, fig. 12.)
- Strophonella milleri Sp. nov.
- Camarotoechia indianensis (Hall). (Plate XV A, figs. 10 A, B.)
- Cypricardinia jepthaensis Sp. nov.
- Hormotoma subluxa (Conrad)
- Lophospira bucheri Sp. nov.

*Trochonema* sp., resembling *Trochonema beloitense* Whitfield in having two lateral revolving ridges, and one ridge near the upper suture, but entire height of shell only 10 mm., and with more acute apical angle. (Plate XV A, fig. 7.)

*Calymene* cf. *cedarvillensis* Foerste

*Iliaenus daytonensis* Hall and Whitfield. (Plate XV A, fig. 13)

***Lyellia* cf. *thebesensis* Foerste**

*Plate XV, fig. 8*

*Lyellia thebesensis* Foerste, Bull. Sci. Lab. Denison Univ., 14, 1909, p. 95, pl. 4, fig. 69.

Corallum 70 mm. in width and 45 mm. in height; maximum size unknown. Corallites averaging 1.5 mm. in diameter, the distances between the corallites averaging between 0.4 and 0.5 mm., two and a half to three corallites occurring in a length of 5 mm. The corallites are tubular in form and are crossed by 8 to 13 tabulae in a length of 5 mm. The spaces between the corallites are crossed by vesicular tissue, the plates of which sometimes are not much closer together than the tabulae within the corallites. When the corallum is viewed from above, this vesicular tissue frequently has a more or less radiating appearance.

Locality and formation.—In the loose chert, assumed to be of Laurel age, on Jephtha Knob, Kentucky.

***Strophonella milleri* Sp. nov.**

*Plate XIV, fig. 9*

Pedicle valve 17.5 mm. long, 23.5 mm. wide at the hinge-line, with the lateral sides converging at an angle of about 36° from the postero-lateral angles toward the antero-lateral ones, and then rounding anteriorly, with a tendency toward angulation in front, somewhat as in *Strophonella costulata* Hall and Clarke. For a distance of 3 to 5 mm. from the beak the valve is distinctly convex, but 8 mm. from the beak the curvature reverses to concave and remains so as far as the margin of the valve. There is a tendency toward depression also along the median line of

the valve along its anterior part, as in the species mentioned above. The radiating striae, however, are much more numerous, numbering 6 to 8 in a width of 3 mm.

Locality and formation.—In the loose chert, assumed to be of Laurel age, on Jephtha Knob, Kentucky.

***Cypricardinia jephthaensis* Sp. nov.**

*Plate XV A, fig. 6*

Right valve 18.5 mm. long, 9.5 mm. high, and 3 mm. deep. Umbo broad and rounded, near the anterior end of the shell. The latter extends only about 2 mm. beyond the beak, there being a faint concave outline between this anterior end and the beak. The general outline of the shell is transversely elliptical, highest at the beak and narrowing but moderately posteriorly. The posterior border is more narrowly rounded than the anterior one. The greatest depth of the valve is at mid-length. There is a slight tendency toward flattening in the umbonal area. The umbonal ridge is weakly defined and lies near the upper margin of the valve. Growth lines are indicated in directions similar to those of *Cypricardinia arata*, but so faint as to be almost imperceptible. Compared with the Racine species, the Jephtha Knob form is more elongate, and its posterior portion is less elevated; moreover, the umbonal part is broader and flatter.

Locality and formation.—From the loose chert, assumed to be of Laurel age, on Jephtha Knob, Kentucky.

***Lophospira bucheri* Sp. nov.**

*Plate XV A, fig. 9*

Shell 40 mm. in height, 32 mm. in maximum width, with a vertical height of 22 mm. at the aperture, and an apical angle of 60°. There are 6 or 7 volutions. Along the last half of the last volution there is a salient peripheral angle extending about 1.5 mm. beyond the general convexity of this part of the shell. Along the corresponding part of the preceding volution the peripheral angle is sharply angular but not salient. Here the upper part of the last volution conceals the lower part of the preceding

volution to a level 4 mm. beneath the peripheral angle of the latter, and corresponding concealment is shown along the upper volutions. Directly over the aperture, the second last volution shows a prominent revolving striation two-fifths of the distance from the suture above to the peripheral angle beneath, along the upper face of the volution. Above and below this revolving striation the upper face of the volution is gently concave. No trace of this revolving striation can be detected along the last half of the last volution. The character of the slit-band on the peripheral angle can not be determined beyond the fact that it is not broad and deep as in *Phanerotrema*. On the last volution fine striae curve backward from the suture above toward the peripheral angle, and on the lower side of this angle they curve at first moderately forward, then vertically downward, and finally moderately backward toward the umbilicus. Apparently there are traces of numerous fine revolving striae, but these traces are so vague that the presence of such revolving striae can not be asserted with confidence. Possibly the shell is related to the group typified by *Lophospira inexpectans*, but in that case the trilineate character of the slit-band should be in evidence, even in a shell whose surface is no better preserved than the one at hand.

Locality and formation.—In the loose chert, assumed to be of Laurel age, on Jephtha Knob, Kentucky. Named in honor of Prof. Walter H. Bucher, of the University of Cincinnati.

***Calymene* cf. *cedarvillensis* Foerste**

*Plate XIII, figs. 10 A, B, C*

*Calymene cedarvillensis* Foerste, Bull. Sci. Lab. Denison Univ., 19, 1919, p. 78, pl. 18, figs. 11 A, B, C.

Fragments of the cranium, thorax, and pygidium indicate the presence of a large species of *Calymene*, certainly equalling 160 mm. and probably equalling 170 mm. in length. It is easily comparable in size, therefore, with the large specimens of *Calymene platys* Green from the Schoharie grit of New York.

Compared with *Calymene cedarvillensis* from the Cedarville dolomite at Cedarville, Ohio, the anterior border of the cranidium and the groove intervening between this border and the anterior margin of the glabella appears relatively broader, from front to rear, in the Jephtha Knob specimens.

Compared with *Calymene vogdesi* Foerste, from the Brassfield limestone of southwestern Ohio, the posterior margin of the pygidium is more strongly curved; the median axis of the pygidium is relatively broader, and the lateral parts are correspondingly narrower in the Jephtha Knob specimens. The median groove on the pleural ribs of the pygidium are distinctly defined only along the more distal parts of these ribs.

Undoubtedly other distinguishing features would be noted if better specimens of the Jephtha Knob, Cedarville, and Brassfield species were at hand.

***Orthis bucheri* Sp. nov.**

*Plate XV A, fig. 14*

Brachial valve 26 mm. long, estimated to have been 32 mm. wide; nearly flat, with a shallow median depression. With 17 or 18 primary radiating plications, alternating with which there is a secondary series, not reaching the beak. Both primary and secondary plications tend to be rather angular along their crests, and not flattened as in typical *Orthis*. The structure of the shell is strongly fibrous.

Locality and formation.—South spur of South Hill on Jephtha Knob, Kentucky; at the base of the crinoidal Brassfield limestone. Collected by Prof. Walter H. Bucher, in whose honor the species is named.

H. TRILOBITES FROM THE ST. CLAIR LIMESTONE OF ARKANSAS

Among the trilobites studied by Prof. Gilbert Van Ingen<sup>38</sup> from the St. Clair limestone at Batesville, Arkansas, the following never were described or figured: *Calymene altirostris*, *Cyphaspis*

<sup>38</sup> Van Ingen, Gilbert, The Silurian Fauna near Batesville, Arkansas, I: School of Mines Quart., vol. 23, 1901, p. 35.

*arkansana*, and *Cyphaspis spinulocervix*. Prof. Van Ingen has very kindly loaned the types of these species to the writer for description, and in these descriptions the names proposed by Prof. Van Ingen have been retained. The collection loaned by Prof. Van Ingen includes also several specimens of a new species of *Proetus*, which I take pleasure in naming after him.

***Calymene altirostris* Sp. nov.**

*Plate XIV, figs. 1 A, B, C*

Two cranidia are at hand which may not belong to the same species. The one in which the anterior or rostral border is most conspicuously elevated undoubtedly is the specimen which suggested the name *altirostris*, and must serve as the type of the species, although it is an inferior specimen otherwise.

Length of cranidium, including the anterior border and the glabella, but lacking the neck-ring, 5.5 mm. Including the neck-ring its original length may have been nearly 6.5 mm. The glabella alone is nearly 4 mm. in length, and its maximum width at the base is estimated at 4.2 mm. The anterior margins of the lateral lobes are approximately 1.5, 2.5, and 3 mm. from the posterior margin of the posterior pair of lobes. The anterior pair is but faintly indicated, while the other two pairs of lobes and the median part of the glabella are strongly convex. The general elevation of the anterior part of the glabella above the lateral parts of the cranidium is about 1.4 mm., and the anterior or rostral border rises nearly 1 mm. above the general antero-posterior curvature of the median part of the glabella. Viewed from in front, the doublure of the rostral part has an elevation of 1.2 mm., and its face rises at an angle of  $95^{\circ}$  with the general horizontal plane of the cranidium, inclining slightly forward from the vertical. The deep groove between the anterior border and the glabella is scarcely a third of a millimeter in width. The anterior margin of the glabella tends to be squarish. The surface of the cranidium is covered by minute granules, visible only under a lens.

The second specimen belonging to the type series of this species is much better preserved. Including the neck-ring, the cranidium is 5.2 mm. in length. The anterior margin of the anterior border extends 1.3 mm. in front of the glabella, the groove between this border and the glabella being 0.25 mm. The glabella tends to be more narrowly rounded anteriorly, and the anterior or rostral border also appears more narrowly rounded. This rostral border is strongly elevated anteriorly, but its upper margin does not rise above the general curvature of the glabella antero-posteriorly.

Notwithstanding the differences noted, the two individuals probably belong to the same species.

**Calymene** sp.

*Plate XIV, figs. 2 A, B, C.*

Four pygidia of the same general appearance are mounted on the same small card, and a fifth specimen, loose, was used for a lateral view. The largest of these originally was 4.8 mm. in length, 7.8 mm. in width, and had a convexity of slightly over 2 mm. anteriorly. The axial lobe is 3 mm. in width anteriorly and rises 0.8 mm. above the adjacent parts of the lateral lobes. The outer part of the lateral lobes curves downward toward the margin of the pygidium, but without any reversal of curvature on approaching the latter. The downward curvature begins along a line corresponding to that described in the case of *Cyphaspis arkansana*, but the downward curvature along this line is less abrupt.

The axial lobe bears 2 distinct rings, anteriorly, behind which there is one ring which is fairly distinct and another ring which is faintly visible; 1 or 2 additional rings may be barely perceptible, and 1 specimen shows a seventh ring. The pleural ribs on the lateral lobes usually are indistinctly marked, except the anterior 2 or 3 pairs, these anterior ribs being grooved along their median lines.

It is the absence of any trace of outward curvature along the margin of the pygidium, and the presence of additional discern-

ible rings on the axial lobe which distinguish the pygidia here described under the name *Calymene* from those referred by Prof. Van Ingen to *Cyphaspis arkansana*.

**Proetus vaningeni** Sp. nov.

*Plate XIV, figs. 3 A, B, C*

Five cranidia are at hand, of which the largest has a length of 5.8 mm. The glabella is 4.7 mm. long, the anterior border of the cranidium is 1.1 mm. long, and the neck-ring is 1 mm. in length. The maximum width of the glabella at its posterior end is 3.9 mm. The glabella is strongly convex, both laterally and antero-posteriorly. In the latter direction its greatest convexity is about one-third of the length of the glabella from its anterior margin. Here the convexity of the glabella is fully 1 mm. Along the posterior two-thirds of the glabella its antero-posterior curvature is distinctly less in an antero-posterior direction, though still fairly strong laterally. No trace of a posterior pair of lobes was detected, though the glabella widens slightly here. In general, the sides of the glabella are nearly parallel, converging slightly toward the front until the inward curvature of the facial sutures in front of the palpebral lobes is reached, but anterior to the latter the sides curve with increasing rapidity and the anterior margin of the glabella is evenly rounded. Along the anterior part of the glabella the antero-posterior curvature of the glabella is so strong that this part of the glabella tends to arch forward over the groove limiting its anterior margin. No area intervenes between the anterior margin of the glabella and the median part of the anterior border of the cranidium for a width of a millimeter and a half. The upper surface of this border is flattish or gently convex, and inclines upward and forward at an angle of about  $160^{\circ}$  with the general horizontal plane of the cranidium. The neck furrow is deep. The neck-ring is unarmed with any median tubercle as far as known. The palpebral lobes are 0.75 mm. in width, and their anterior margin extends 2.4 mm. in front of the rear margin of the glabella. The surface of the cranidium is almost smooth, even under a lens.

One of the small cranidia is 4 mm. in length, but it is well preserved.

***Cyphaspis spinulocervix* Sp. nov.**

*Plate XIV, figs. 4 A, B, C*

Three specimens belong to the type series. Of these only one presents the long nuchal spine, and this specimen must, therefore, be considered the type.

Glabella 1.5 mm. in length; 0.75 mm. in width posteriorly, including the lateral lobes, 0.8 mm. in width along the neck furrow, excluding these lobes. The lobes are 0.6 mm. in length. The width of the neck-ring is 0.2 mm., and the nuchal spine extends 1.8 mm. beyond the posterior margin of this ring. The spine is long and narrow and starts off abruptly from the posterior margin of the ring. The glabella is strongly convex, and only the posterior margin of the area intervening between the glabella and the anterior border of the cranium is shown.

The second specimen retains only the point of attachment for the nuchal spine, but the spine itself is missing. The remainder of the specimen, however, is well shown. The length of the cranium is 4.1 mm. Of this length 2.5 mm. belongs to the glabella, 0.4 mm. to the neck-ring, and 1.2 mm. to that part of the cranium which is in front of the glabella. The width of the glabella including the lateral lobes is almost 3 mm.; excluding these lobes its width posteriorly is 1.4 mm. The length of the lobes is 0.9 mm. Their form is ovate. The space between the anterior margin of the glabella and the anterior border of the cranium is 0.8 mm. in length, 0.4 mm. being occupied by the anterior border. A narrow, deeply impressed groove borders the anterior and antero-lateral parts of the glabella. Immediately anterior to this groove the cranium is distinctly convex antero-posteriorly. A similar narrow groove borders the posterior margin of the anterior border of the cranium. This border inclines upward and forward at an angle of about  $135^{\circ}$  with the general horizontal plane of the cranium. The glabella, its lobes, and the area intervening between the glabella and the anterior border of the cranium are relatively coarsely

granulated, considering the small size of the specimen, 5 to 6 granules occurring in a distance of 1 mm. Along the neck-ring and fixed cheeks the granules are less prominent, and along the anterior border of the cranidium they can be detected with difficulty.

The third specimen belonging to the type series does not add to the information given by the preceding specimens.

***Cyphaspis arkansana* Sp. nov.**

*Plate XIV, figs 5 A, B, C*

Four pygidia are present in the type series, and of these the largest is 3.6 mm. in length, 5.6 mm. in width, and about 2 mm. in maximum convexity anteriorly. The axial lobe originally was 2.5 mm. in width anteriorly; at present only the cast of the lower surface of the pygidium remains. Originally this axial lobe rose strongly above the adjacent parts of the lateral lobes; possibly 1 mm. The greater part of the lateral lobes curves strongly downward toward the lateral margins of the pygidium, the downward curvature beginning along a line extending from a point 0.8 mm. from the anterior end of the lateral margin of the axial lobe diagonally backward and inward, so as to continue around the posterior margin of the axial lobe in a U-shaped direction. Parallel to the posterior and lateral margins of the pygidium, along a line passing immediately posterior to the axial lobe, there is a faint tendency toward an outward or concave curvature, visible only under favorable illumination. It may be this faint outward curvature along the margin which suggested the reference of these pygidia to *Cyphaspis*, rather than to *Calymene*.

The axial lobe bears 2 distinct rings with indistinct indications of a third ring. Posterior to these there is room enough for 3 additional rings, but the surface of the axial lobe here usually is smooth. The pleural ribs are weakly indicated. The anterior pair show median grooves. The third pair is too faintly indicated to give evidence of grooving. Nothing can be identified distinctly farther back.

No glabellae accompany these pygidia belonging to the type series. I am unable to discriminate between the glabellae of *Cyphaspis*, *Proetus*, and *Calymene* in specimens of such small size, but regard *Cyphaspis* as a possibility in the case of the pygidia here described.

I. A NEW GASTEROPOD FROM THE GUELPH FORMATION OF OHIO

*Straparollus paveyi* Sp. nov.

Plate XV, figs. 1 A, B, C

Shell strongly depressed; greatest lateral diameter 63 mm.; height 37 mm. The spire rises about 20 mm. above the last volution at its aperture. Volutions at least 5, possibly 6. The suture between the last volution and that immediately preceding is about two-fifths of the height of the latter above its base. From this suture downward for a short distance the upper part of the inner outline of the cross-section of the last volution is distinctly though moderately concave. Along the remainder of its contour this outline is approximately circular, but slightly depressed vertically, and with a tendency toward oblique flattening of that part of its slope which is immediately above mid-height of the last volution. Near the aperture, the lateral diameter of the last volution is 23.5 mm., and its vertical diameter is 22 mm. The oblique flattening above mid-height forms an angle of about 30° with the vertical axis of the shell. The umbilicus is wide and open, showing all of the volutions; its greatest diameter in the specimen here described is 20 mm.

Owing to the oblique flattening of that part of the last volution which is immediately above mid-height there is a tendency toward a shoulder about three-fifths of the distance between mid-height and the suture above. From the suture as far as the middle of the obliquely flattened slope, the transverse striae curve backward at an angle of about 80° with the suture. From this point the striae curve more strongly backward, at an angle of 60° with the horizontal, until about 3 mm. below mid-height of the volution, beyond which they curve forward until they assume a radial direction along the lower face of the volution. There is a tend-

ency toward angulation along the lower margin of the umbilicus, and within the umbilicus the inner side of the last volution is striated by relatively coarse transverse lines which curve so as to present their concave sides toward the aperture of the shell. In addition to the conspicuous transverse striae, there are very faint, almost obsolete, revolving ridges, not likely to be noticed except on exceptionally well preserved specimens.

Locality and formation.—Hillsboro, Ohio; from the Guelph formation. From the collection of Henry Pavey, in whose honor this species is named. Similar specimens are found in the Racine of Wisconsin and the Chicago area.

Remarks.—*Straparollus paveyi* is regarded as related to the species described by Lindström<sup>39</sup> under the name *Oriostoma discors* Sowerby. In the American species the revolving ridges have become obsolete.

#### J. A STIGMARIAN ROOT FROM THE CHESTER FORMATION OF ILLINOIS

##### *Dictyophlois* Foerste

In the Bulletin of the Torrey Botanical Club, in 1916, a Stigmarian root from the Chester formation at Sample, Kentucky, was described under the new generic name *Dictyophlois*, the species itself being named *Dictyophlois reticulata* Foerste.

Similar Stigmarian roots had long been known in Europe under the name of *Stigmaria stellata* or *Stigmaria ficoïdes stellata*. As long ago as 1841, Goeppert illustrated this form of root in his *Gattungen der Fossile Pflanzen* (pl. X, fig. 12) from Silesia. It appears to range from Great Britain as far east as Russia.

In Europe, *Stigmaria ficoïdes stellata* appears to range over about the same territory and at about the same horizon as *Lepidodendron Volkmannianum* Sternberg, which suggests that *Stigmaria ficoïdes stellata* may belong to the root system of *Lepidodendron Volkmannianum*. Both appear to be especially characteristic of the Culm.

In America, Stigmarian roots of this type are confined to the Chester. *Dictyophlois reticulata*, as already stated, was found

<sup>39</sup> Lindström, Sil. Gast. and Pter. of Gotland; 1884, pl. 16, figs. 20-36.

in the Chester at Sample, in Breckenridge county, Kentucky. In the State Museum of Natural History at Springfield, Illinois, there is a specimen of *Dictyophlois*, numbered 1718, labelled as coming from the Chester group, at Carroll's place, in Pope county, Illinois. This specimen is described and figured on the following pages. I have been informed by Dr. David White that *Stigmariamian* roots of the *Dictyophlois* type are known also in Appalachian areas, in strata of Chester age.

Whether *Dictyophlois* is to be regarded as founded on differences of generic value can not be determined until its relationship to known aerial stems has been definitely established. In our present state of knowledge it appears to be as distinct as many another genus. Certainly, the reticulated appearance of the area between the attachment areas of the so-called rootlets looks quite different from the corresponding relatively smooth area in *Stigmaria ficoides*.

If a knowledge of the bark and wood structure of the so-called roots or rhizophores of *Dictyophlois* and of *Stigmaria ficoides* were known, it would be possible to determine what is the significance of the reticulated structure on the supposed surface of *Dictyophlois*. No specimens showing such structure are at hand. Therefore, I am forced to base my opinions on such features as are exposed merely by impressions of the surface in its present condition, without any knowledge as to whether these features belong to the original surface of the bark, or to more deep seated structures within this bark.

The American specimens of *Dictyophlois* do not appear to be identical specifically with *Stigmaria ficoides stellata* as figured by Goeppert. The reticulations between the attachment areas of the rootlets appear more complicated, although a change of opinion might be necessary if actual specimens of the European form were at hand.

The figure accompanying the original illustration of *Dictyophlois reticulata* unfortunately was printed in an inverted position, as the location of the shadows might indicate. It was also printed altogether too pale to bring out all of the structure. This is remedied by the illustrations of the Illinois specimen here presented.

**Dictyophlois reticulata illinoisensis** Var. nov.

*Plate XII, and plate XIII, fig. 12.*

Cf. *Dictyophlois reticulata* Foerste, Bull. Torrey Bot. Club, 42, 1916, p. 675, pl. 33.

Plate XII presents the appearance of the specimen in its present condition. Figure 12 on plate XIII presents the appearance of an impression of a part of the same specimen, in which the cavities of the first figure stand out as projections.

Specimen 150 mm. in length and about 80 mm. in width; part of a rhizophore, whose original diameter can not be determined. In its present condition the specimen is flattened. The view presented on plate XII is assumed to be that of the exterior of the cortex. The round areas of attachment of the so-called rootlets vary from 3 to 4, occasionally 5 mm. in diameter. They tend to be arranged in diagonally intersecting rows, so as to be from 8 to 13 mm. apart. At these attachment areas the surface of the rhizophore is abruptly depressed, and from the bottom of the pit there rises a short circular elevation with a small central pit. Some of these small central pits have a central tiny elevation. The round areas of attachment are surrounded by a single series of radiating depressions, usually from 20 to 25 in number. These radiating depressions vary usually from 2 to 3 mm. in length, but occasionally are shorter or longer. In the areas between the radiating groups of depressions the meshes of the remainder of the reticulated surface usually average about 2 mm. in diameter, though a few may be as much as 3 mm. in diameter.

Locality and formation.—From the Carroll place, in Pope county, in the southern extremity of Illinois, in the Chester formation.

Remarks.—Evidently the structure of this Illinois specimen is very similar to that of the Kentucky type. The question arises whether they are identical. Apparently the zone of radiating depressions surrounding the attachment areas of the rootlets tends to be depressed below the general level of the surface in the Kentucky type, while in the Illinois specimen the descent

into the pit at the attachment area is more abrupt; but this may be due to inferior preservation of the Kentucky type. In the Kentucky type these attachment areas vary from 13 to 15 mm. in their distances apart as an average, and considering this moderately greater distance apart, the meshes of the reticulated surface between appear relatively coarser. In fact, this difference in the coarseness of the intervening meshes appears sufficient to warrant the use of a distinguishing name for the Illinois specimen, which therefore is called variety *illinoisensis* of the Kentucky type of *Dictyophlois reticulata*.

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## PLATE IV

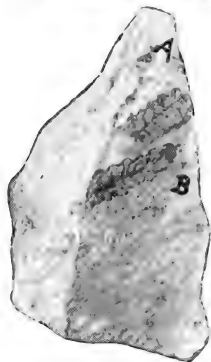
Fig. A. *Leveilleites hartnageli* Foerste. Type, in same slab with *Dictyonema scalariforme creditensis* Foerste. Specimen belonging to Chris Andrew Hartnagel.

Fig. B. *Dictyonema scalariforme creditensis* Foerste. Type, magnified 1.7 diameters. The lower part of the specimen presents the proximal side and the upper part the distal side of the same infundibuliform rhabdosome.

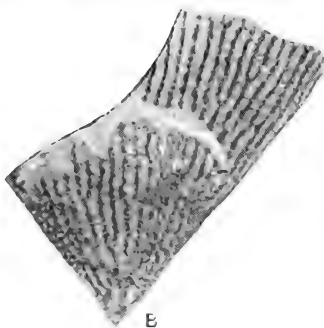
Fig. 25. *Leveilleites hartnageli* Foerste. Both obverse and reverse of the specimen are present. Enlarged views occur on plate IX.

Fig. 26. *Leveilleites hartnageli* Foerste. Reverse of specimen 5. Enlargements of specimens 26 and 5 occur on plates VII and X.

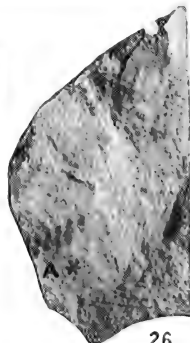
All specimens on this plate are from the base of the Manitoulin dolomite member of the Medinan, in the quarry west of Credit Forks railroad station, in Ontario.



25



E



26

## PLATE V

Figs. 1-12. *Leveilleites hartnageli* Foerste, associated with *Dictyonema scalariforme creditensis* Foerste in specimens 4 and 12. Credit Forks, Ontario; in the Manitoulin dolomite.

The fronds in the upper right hand corner of figure 2 are the reverse of those in figure 15 on plate VI.

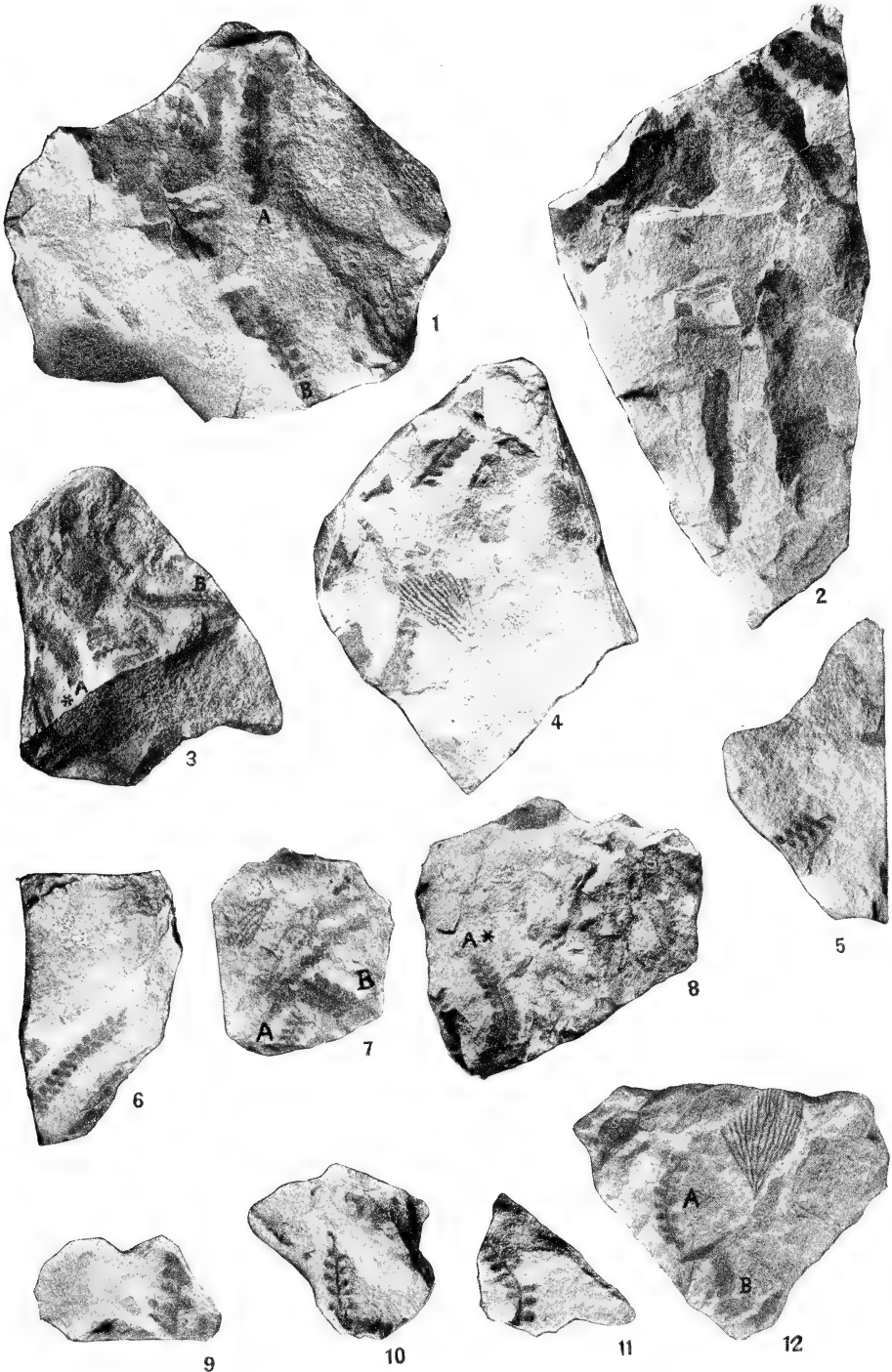
Of specimen 3 both the obverse and reverse are present, and frond A is enlarged on plate VII.

Specimen 5 is the reverse of specimen 26 figured on plate IV, and both are figured enlarged on plates VII and X.

Of specimen 6 both the obverse and reverse are present, and a third fragment contains *Dictyonema scalariforme creditensis*.

Specimen 7 is the reverse of specimen 21, frond B in figure 7 and frond A in figure 21 being the frond enlarged in figure 21 on plate IX. Specimen 8 is the reverse of the opposite side of specimen 21, no part of which is shown in figure 7.

Frond A in figure 8 is enlarged on plate VIII.



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PLATE VI

Figs. 13-24. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario,  
in the Manitoulin dolomite.

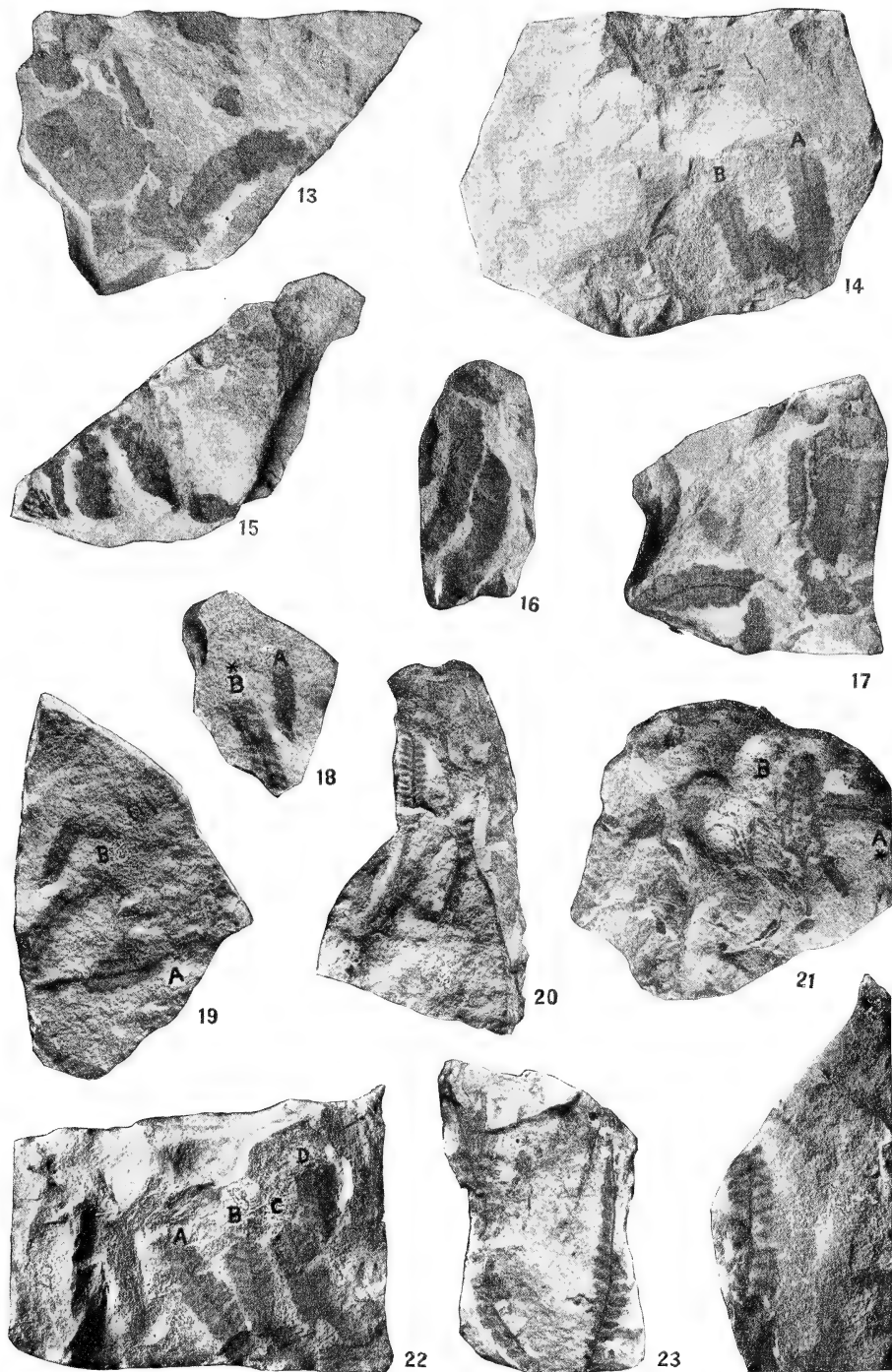
Specimen 13 is the reverse of specimen 17.

Specimen 15 is the reverse of the upper part of specimen 2.

Specimen 16 is the reverse of specimen 22.

Specimen 18 is the reverse of specimen 19, and is enlarged on plate XI.

Specimen 21 is the reverse of specimen 7, and is enlarged on plate IX.



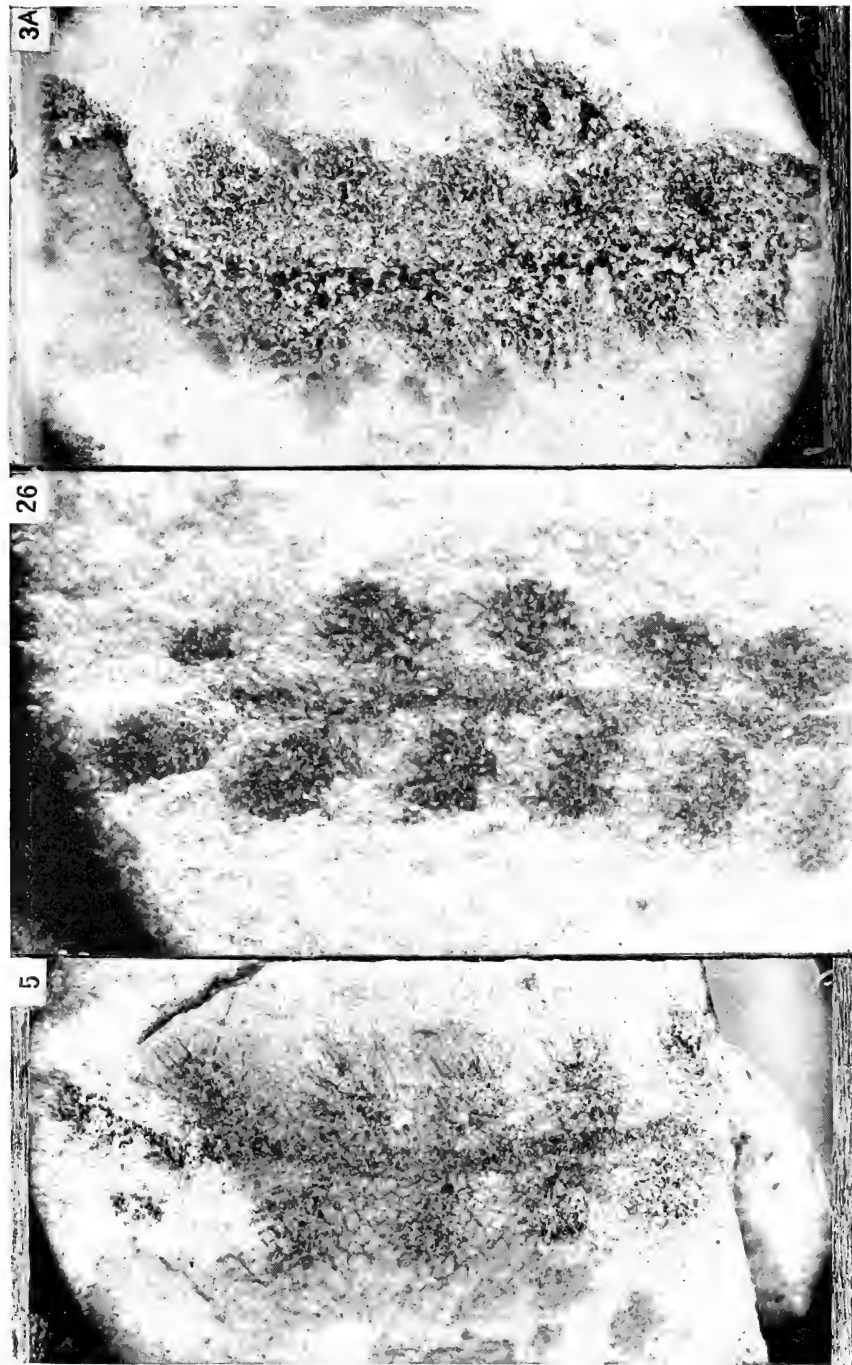
#### PLATE VII

Fig. 3A. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. View of frond 3A on plate V enlarged 10 diameters. Showing trace of median rachis-like film.

Fig. 5. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. View of frond in figure 5 on plate V, enlarged 10 diameters. Reverse of specimen 26. Reticulated structure of frond shown vaguely in dark part of figure. See also plate X.

Fig. 26. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. View of frond A in figure 26 on plate IV, enlarged 10 diameters. Showing the reticulated structure of the frond.

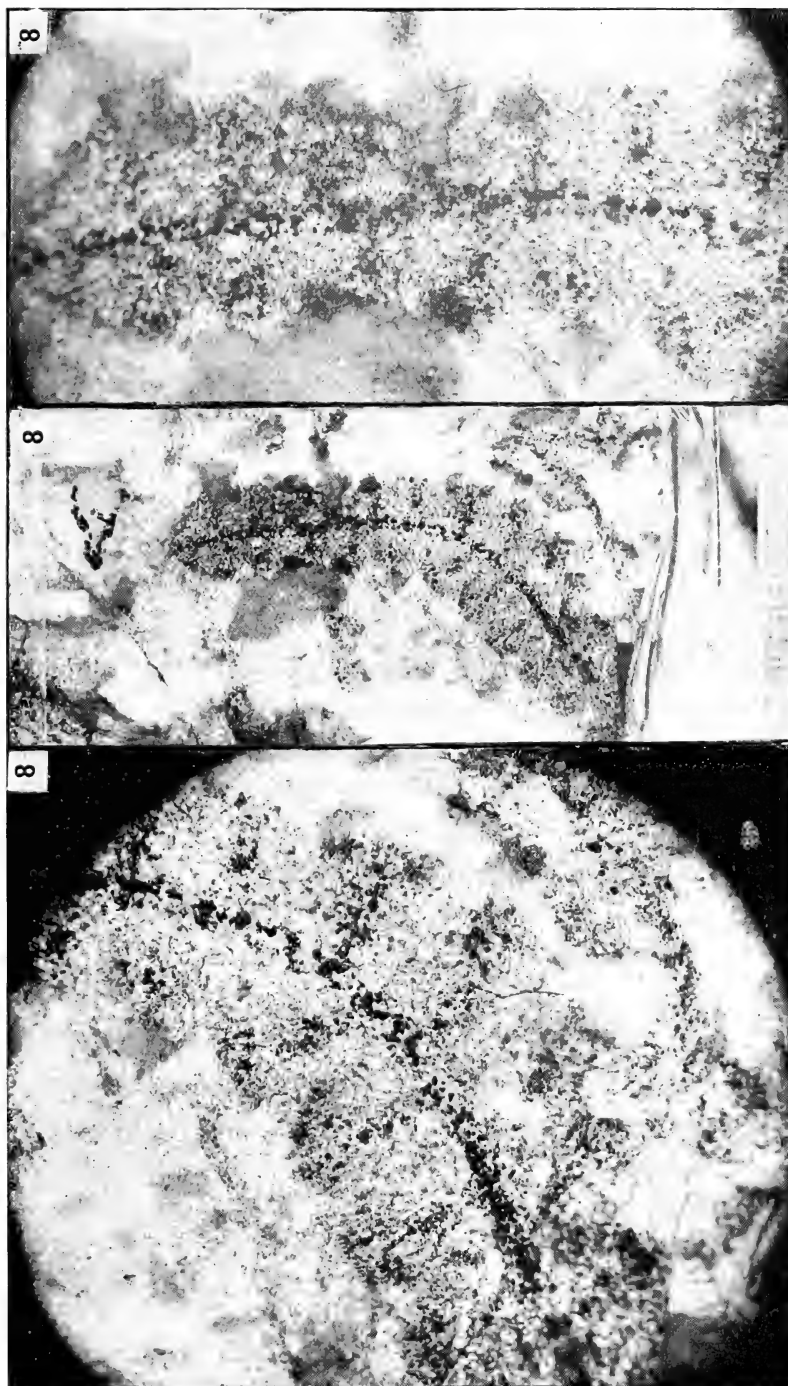
Photographs by Prof. George H. Hudson, of Plattsburgh, New York; this and the following four plates have been photographed under gum dammar in order to bring out the structural details. Plates X and XI should be examined under a stereoscope.



#### PLATE VIII

Fig. 8. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. View of frond A in figure 8 on plate V. The middle figure is enlarged 4 diameters. The right hand figure, enlarged 10 diameters, represents the upper half of the same frond, while the left hand figure, also enlarged 10 diameters, represents the lower part of this frond. All figures show the median rachis-like black film. There are traces also of the reticulated structure.

Photographs by Prof. George H. Hudson.

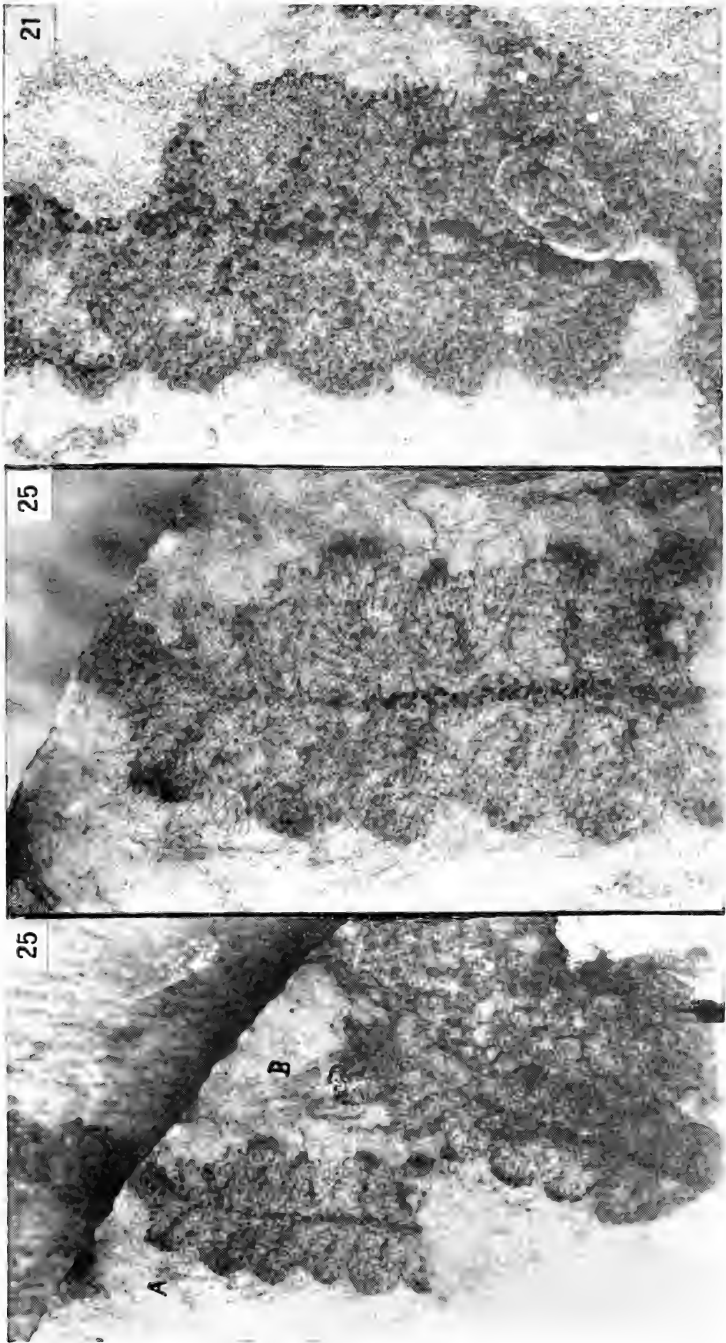


## PLATE IX

Fig. 21. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. View of frond A in figure 21 on plate VI, enlarge 14 diameters. The median rachis-like black film with traces of corresponding lateral films are shown.

Fig. 25. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. The left hand figure is enlarged 4 times, and the middle figure is enlarged 8 times. The middle figure is an enlargement of frond A in the preceding figure, and both figures are enlargements of figure 25 on plate IV. These enlargements show the median rachis-like black films of the fronds and of their lateral lobes, and the reticulated structure of the fibrous mass forming the fronds. Along the left margin of the middle figure on this plate the hair-like fibers attached to the frond are visible in the photograph, but do not show up well in the photoengraving.

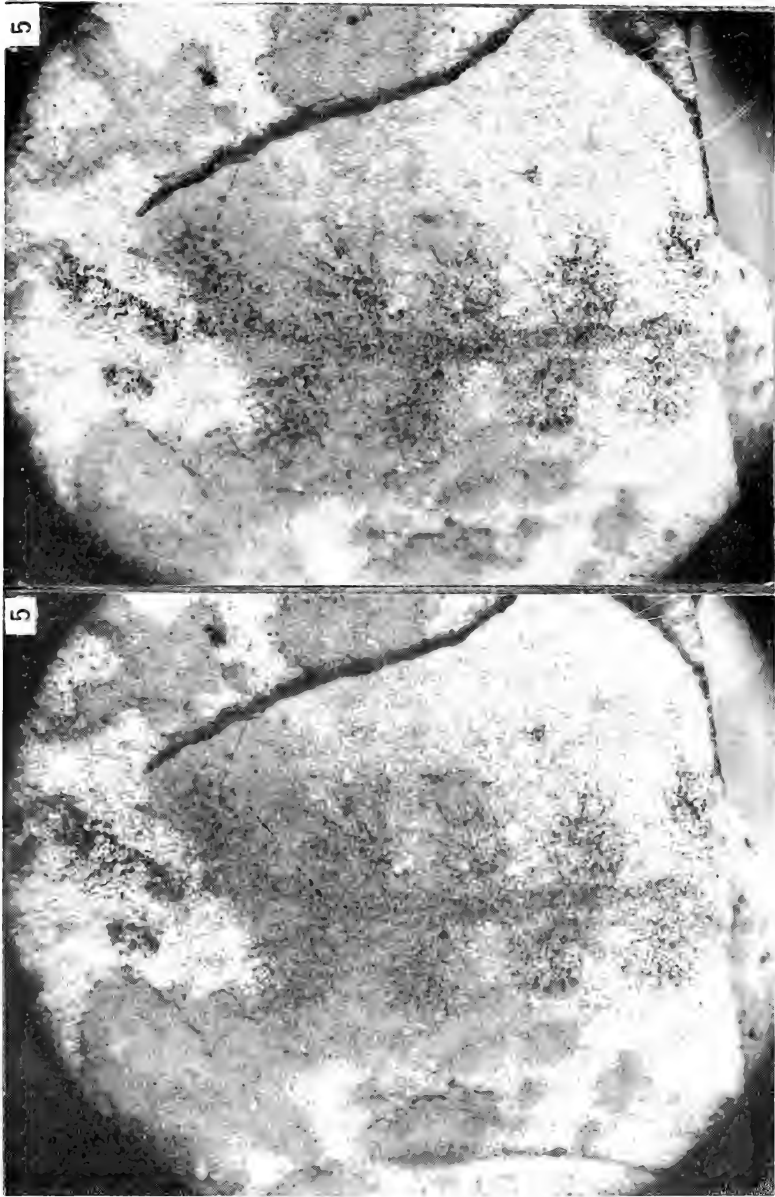
Photographs by Prof. George H. Hudson.



#### PLATE X

Fig. 5. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. Both views enlarged 10 diameters, arranged for use with a stereoscope. Same specimen as figure 5 on plate V. This stereoscopic view is valuable chiefly for showing that the fronds consist of something more than a thin flat carbonaceous film. They consist of reticulating fibers occupying a visible depth of space. Some of the black dots to which the hair-like fibers were attached are visible in the photographs, and a few of the hair-like fibers are seen.

Photographs by Prof. George H. Hudson.



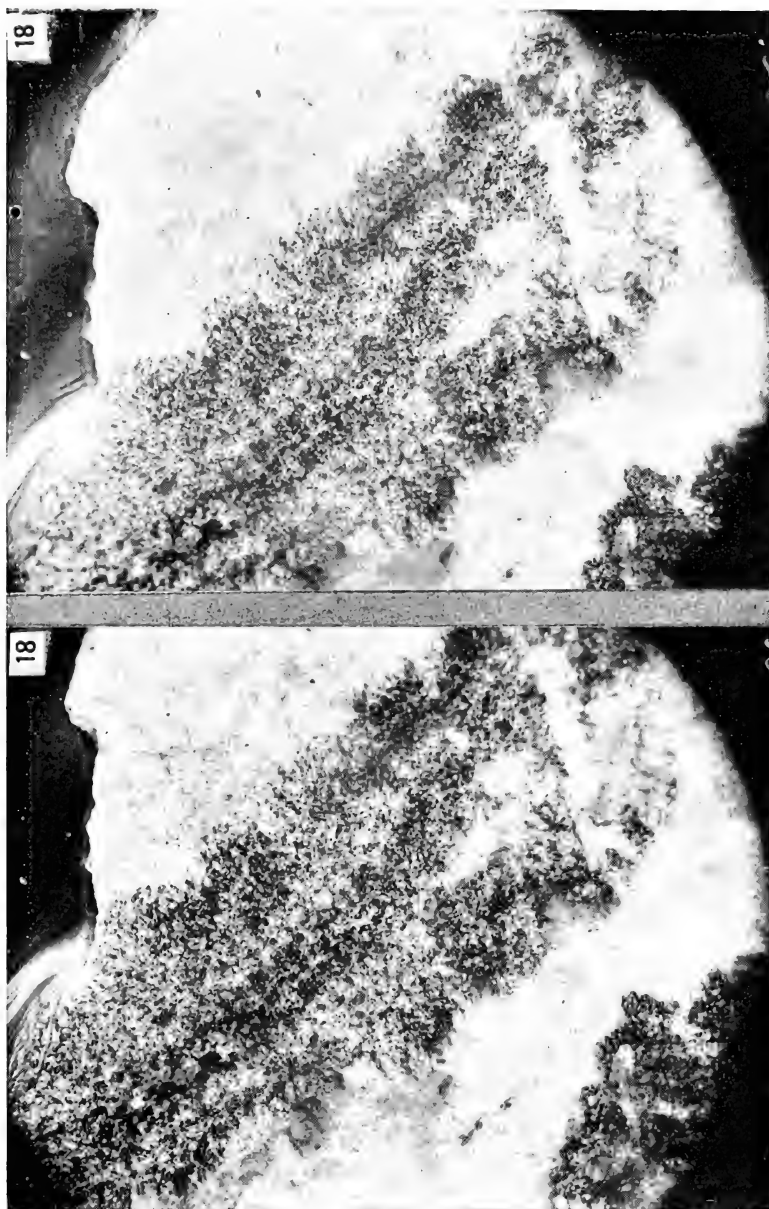
AUG. F. FOERSTE

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#### PLATE XI

Fig. 18. *Leveilleites hartnageli* Foerste. From Credit Forks, Ontario. Both views are enlarged 10 diameters, arranged for use with a stereoscope. Same specimen as figure 18 on plate VI. This stereoscopic view is valuable chiefly for showing that the fronds consist of something more than a thin flat carbonaceous film. Some of the individual fibers can be recognized along the margin of the frond.

Photographs by Prof. George H. Hudson.



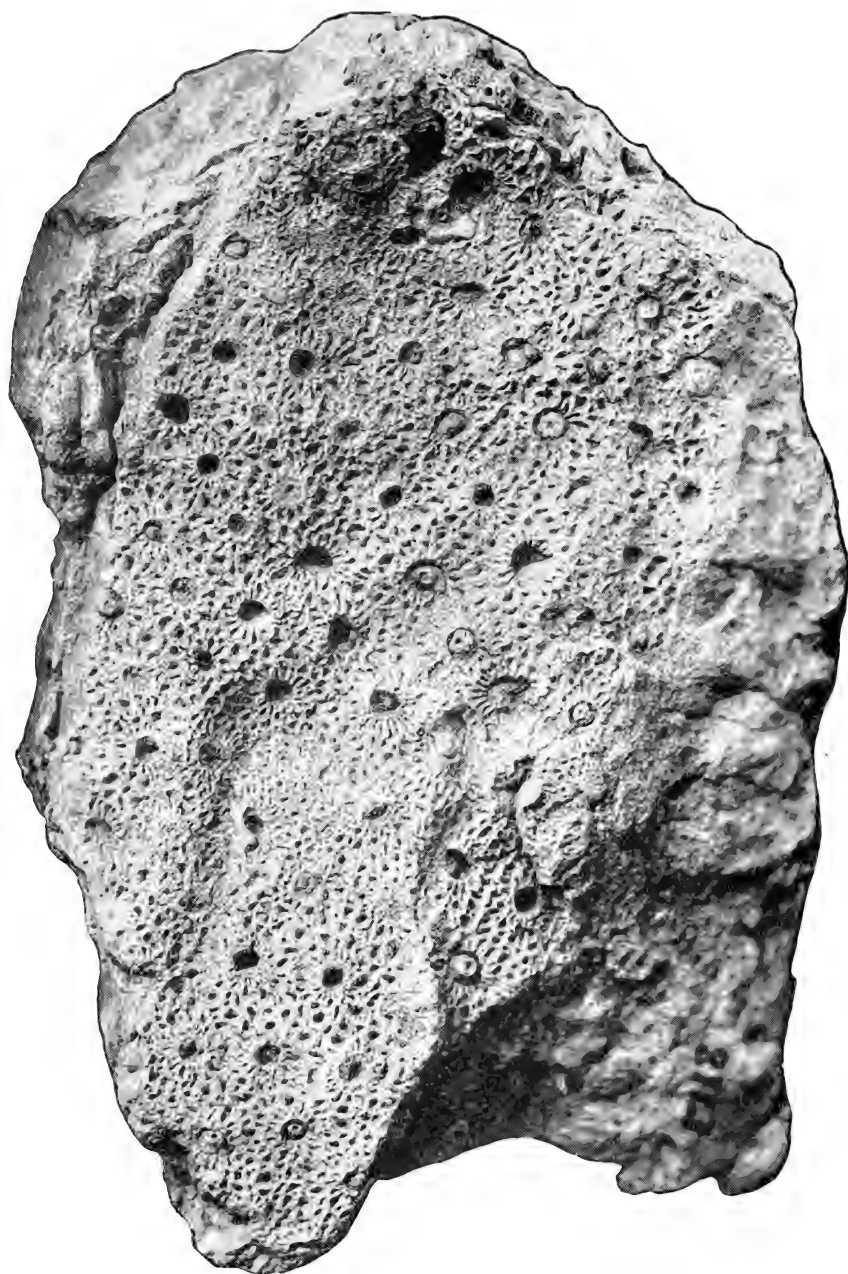
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## PLATE XII

*Dictyophlois reticulata illinoisensis* Foerste. Apparently the outer surface of the bark of one of the rhizophores, showing the circular areas of attachment of the so-called rootlets, and the intervening reticulated area. See Plate XIII for a figure of an impression in clay of part of this specimen. From Carroll place, in Pope county, Illinois.

Specimen No. 1718, State Museum of Natural History, Springfield, Illinois.



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### PLATE XIII

Fig. 1. *Modiolopsis orthonota perumbonata* Foerste. Right valve. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 2. *Modiolopsis orthonota* (Conrad). A-E, right valves; F, G, left valves. Credit Forks Ontario; Whirlpool sandstone.

Fig. 3. *Ctenodonta* (?) *creditensis* Foerste. Left valve. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 4. *Ctenodonta* (?) *catractensis* Foerste. Left valve. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 5. *Ctenodonta* (?) sp. Left valve. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 6. *Schuchertella creditensis* Foerste. Pedicel valve, showing location and length of dental lamellae. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 7. *Dalmanella eugeniensis* Williams. Brachial valve. Credit Forks, Ontario; Whirlpool sandstone.

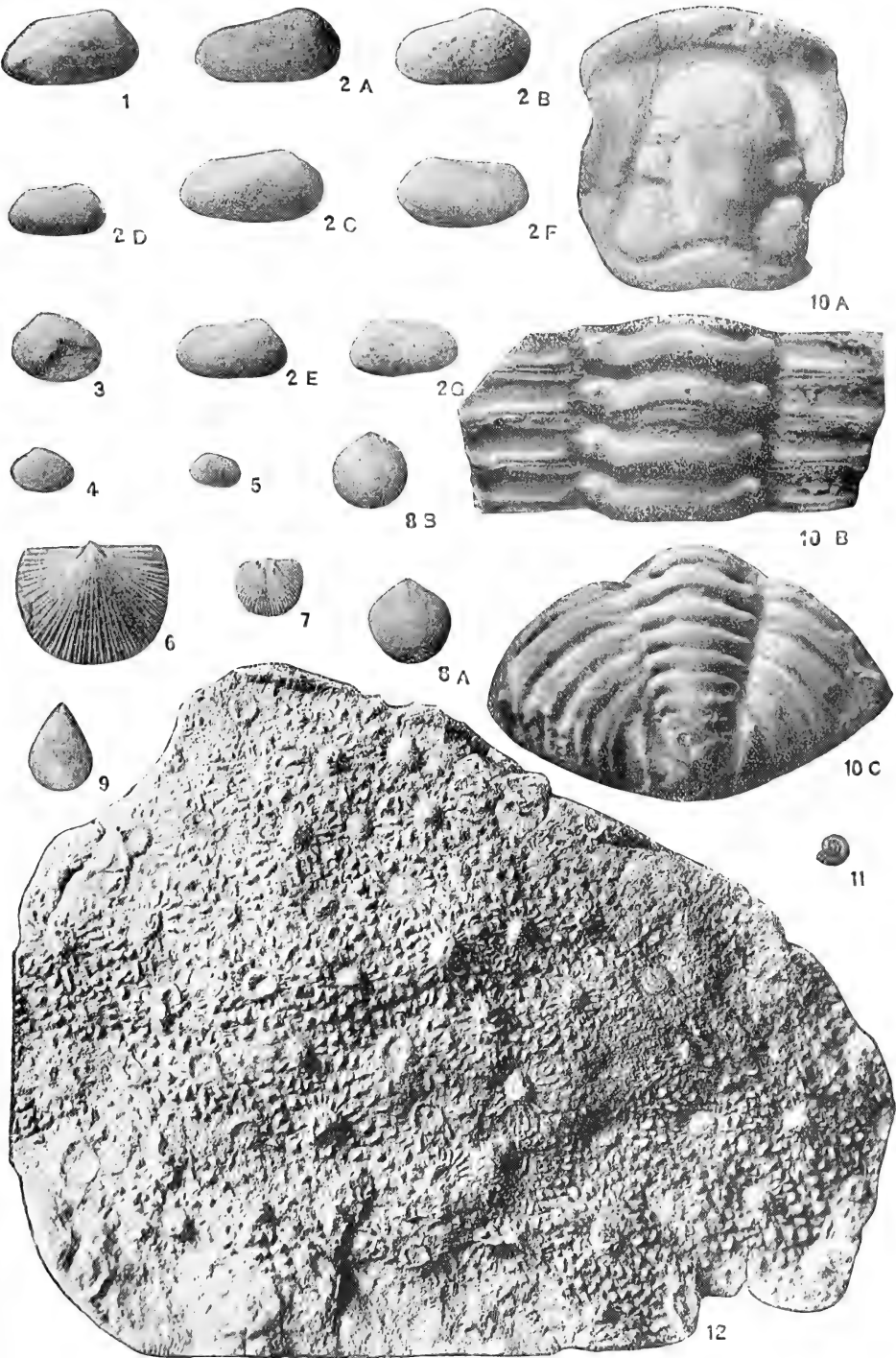
Fig. 8. *Whitfieldella circularis* Foerste. Brachial valves. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 9. *Lingula* cf. *cuneata* Conrad. Brachial valve. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 10. *Calymene* cf. *cedarvillensis* Foerste. A, cranidium. B, fragment of four segments of thorax. C, pygidium. From residual chert, regarded as belonging in the Laurel member of the Niagaran, loose on top of Jephtha Knob, in Shelby county, Kentucky.

Fig. 11. *Liospira* (?) sp. Credit Forks, Ontario; Whirlpool sandstone.

Fig. 12. *Dictyophlois reticulata illinoisensis* Foerste. Clay cast of part of surface of the specimen illustrated on plate XII.



## PLATE XIV

Fig. 1. *Calymene altirostris* (Van Ingen) Foerste. A, cranidium. B, C, lateral and upper views of cranidium of chief type. St. Clair Spring, Independence county, Arkansas; St. Clair member of Niagaran. Types. Van Ingen collection. A, magnified 3 diameters; B, C, 2 diameters.

Fig. 2. *Calymene* sp. A, B, C, three pygidia. C, lateral view. St. Clair Spring, Independence county, Arkansas; St. Clair member of Niagaran. Van Ingen collection. Magnified 3 diameters.

Fig. 3. *Proetus vaningeni* Foerste. A, B, C, three cranidia. St. Clair Spring, Independence county, Arkansas; St. Clair member of Niagaran. Van Ingen collection. Magnified 3 diameters.

Fig. 4. *Cyphaspis spinulocervix* (Van Ingen) Foerste. A, B, C, three cranidia. B, C, showing the points of attachment of the nuchal spine. St. Clair Spring, Independence county, Arkansas; St. Clair member of Niagaran. Van Ingen collection. Magnified 3 diameters.

Fig. 5. *Cyphaspis arkansanum* (Van Ingen) Foerste. A, B, C, three pygidia, with a tendency toward a faint marginal depression. St. Clair Spring, Independence county, Arkansas; St. Clair member of Niagaran. Van Ingen collection. Magnified 3 diameters.

Fig. 6. *Straparollus pervetustus* (Conrad). Viewed slightly obliquely, so as to show more of the spire. Lockport, New York; from the Medinan. Original of fig. 3a on plate 4 bis, Pal. New York, 1, 1847. Specimen No. 1434-1, American Museum of Natural History.

Fig. 7. *Modiolopsis orthonota* (Conrad). A, right valve; B, left valve. Originals of figures 1a, 1b, 1c, on plate 4 bis, Pal. New York, 1, 1847. A, from Medina, New York; B, from Lockport, New York; both from the Medinan. Specimen A, No. 1433-1; specimen B, No. 1433-2, in the American Museum of Natural History.

Fig. 8. *Modiolopsis primigenia* (Conrad). Left valve, cast of interior, showing hinge-tooth. Lockport, New York, in the Medinan. Original of fig. 2a on plate 4 bis, Pal. New York, 1, 1847. Specimen No. 1432-2, American Museum of Natural History.

Fig. 9. *Strophonella milleri* Foerste. Pedicel valve. Jephtha Knob, Kentucky, in loose chert from the Laurel formation.

Fig. 10. *Dalmanites* sp. Fragment from right side of pygidium; outline of pygidium unknown. Centerville, Ohio; from basal Silurian, beneath Brassfield limestone.

Fig. 11. *Leptaena centervillensis* Foerste. A, pedicel valve, interior; B, cast of same, to show convexity of valve. Concentric wrinkles are present, as described in the text, but do not show in the photograph, since the direction of illumination chosen was that which brought out the details of the muscular area, rather than the wrinkles. Centerville, Ohio; from the upper part of the Brassfield limestone.

Fig. 12. *Brachyprion* sp. Interior of pedicel valve. Centerville, Ohio; from basal Silurian, beneath the Brassfield limestone.

Fig. 13. *Schuchertella subplana brevior* Foerste. Pedicel valve. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 14. *Whitfieldella* cf. *ovoides* Savage. A, lateral view; B, cast of interior of pedicel valve. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

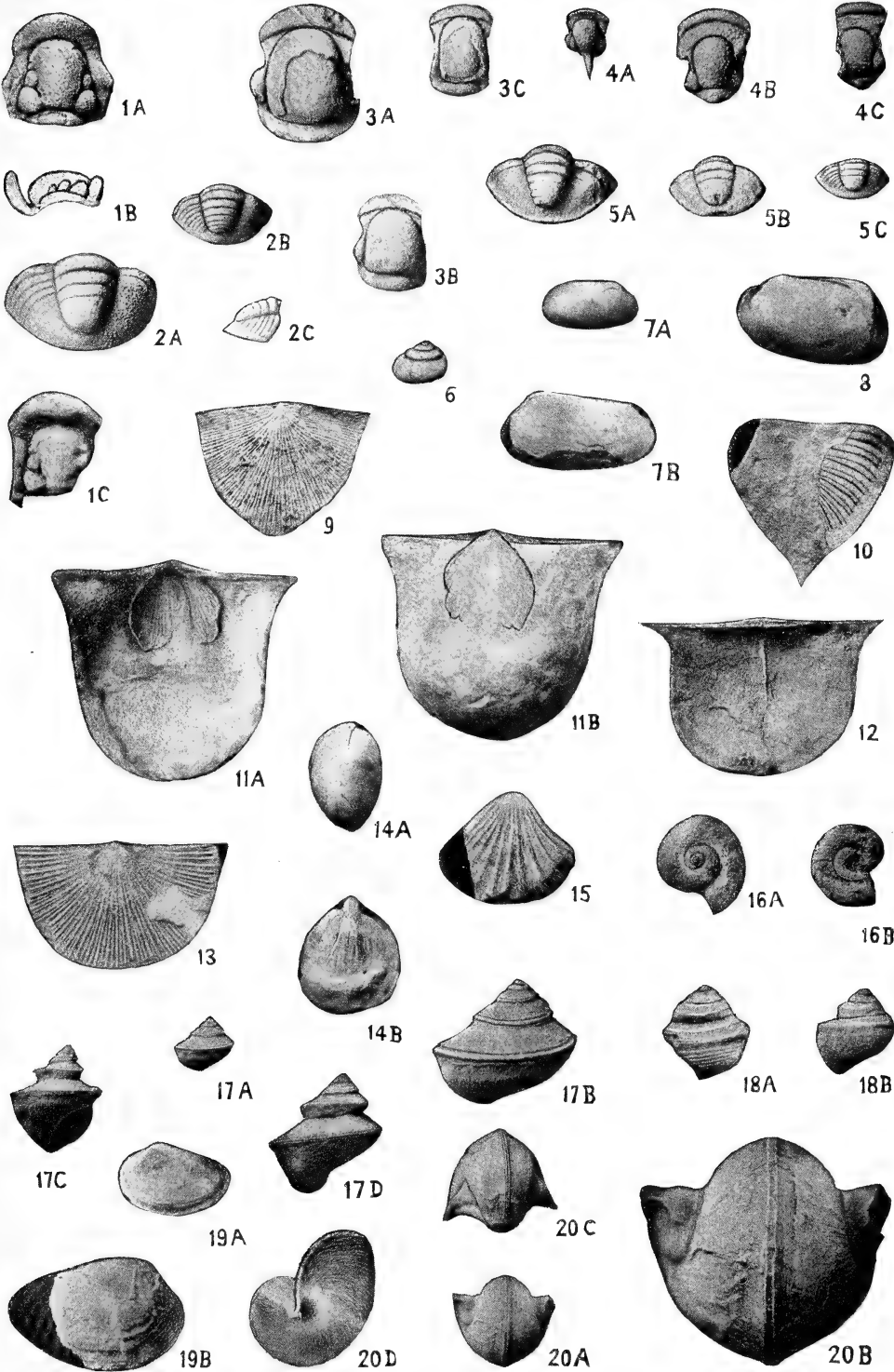


Fig. 15. *Rhynchotretha thebesensis* Foerste. Brachial valve. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 16. *Liospira depressum* Foerste. A, apical view; B, basal view, showing callosity on one side of umbilicus. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 17. *Lophospira ehlersi* Foerste. A, apical part of specimen; B, same specimen enlarged; C, D, entire specimens. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 18. *Lophospira* (*Ruedemannia* ?) *centervillensis* Foerste. A, fragment showing the typical revolving striae along the lower part of the last volution; B, entire specimen, showing general form of shell. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 19. *Ctenodonta* cf. *simulatrix* Ulrich. A., left valve; B, right valve; both magnified 2.4 diameters. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 20. *Bellerophon centervillensis* Foerste. A, aperture facing upward, but margin broken off; B, enlarged view of the same. C, aperture facing downward, but margin broken off. D, attempt at restoration of the margin, in a lateral view.

#### PLATE XV

Fig. 1. *Straparollus paveyi* Foerste. A, lateral view; B, apical view; C, umbilical view, Hillsboro, Ohio; from the Guelph formation.

Fig. 2. *Spyroceras microtextile* Foerste. A, small fragments; B, the same enlarged; this fragment shows the vertical and transverse striae described in the text, but a greater magnification is needed to show these. C, a longer specimen, apparently belonging to the same species. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 3. *Loxoceras husseyi* Foerste. A, a small fragment showing the vertical surface striae; B, enlargement of the same; C, a typical specimen of larger size, showing the camerae; D, vertical section, showing two of the segments of the siphuncle, and faint traces of two more. Centerville, Ohio; from the basal Silurian beneath the Brassfield limestone.

Fig. 4. *Hormotoma trilineata* var. Foerste. Specimen with a shorter spire than usual. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 5. *Hormotoma trilineata* var. Foerste. Specimen with shorter volutions than usual. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 6. *Hormotoma trilineata* Foerste. A, typical form; B, enlargement of the same; C, another specimen. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 7. *Hormotoma centervillensis* Foerste. A, lateral view; B, enlargement of the same. Centerville, Ohio; from the basal Silurian, beneath the Brassfield limestone.

Fig. 8. *Lyellia thebesensis* Foerste. Jephtha Knob, Kentucky, from loose chert referred to the Laurel formation.

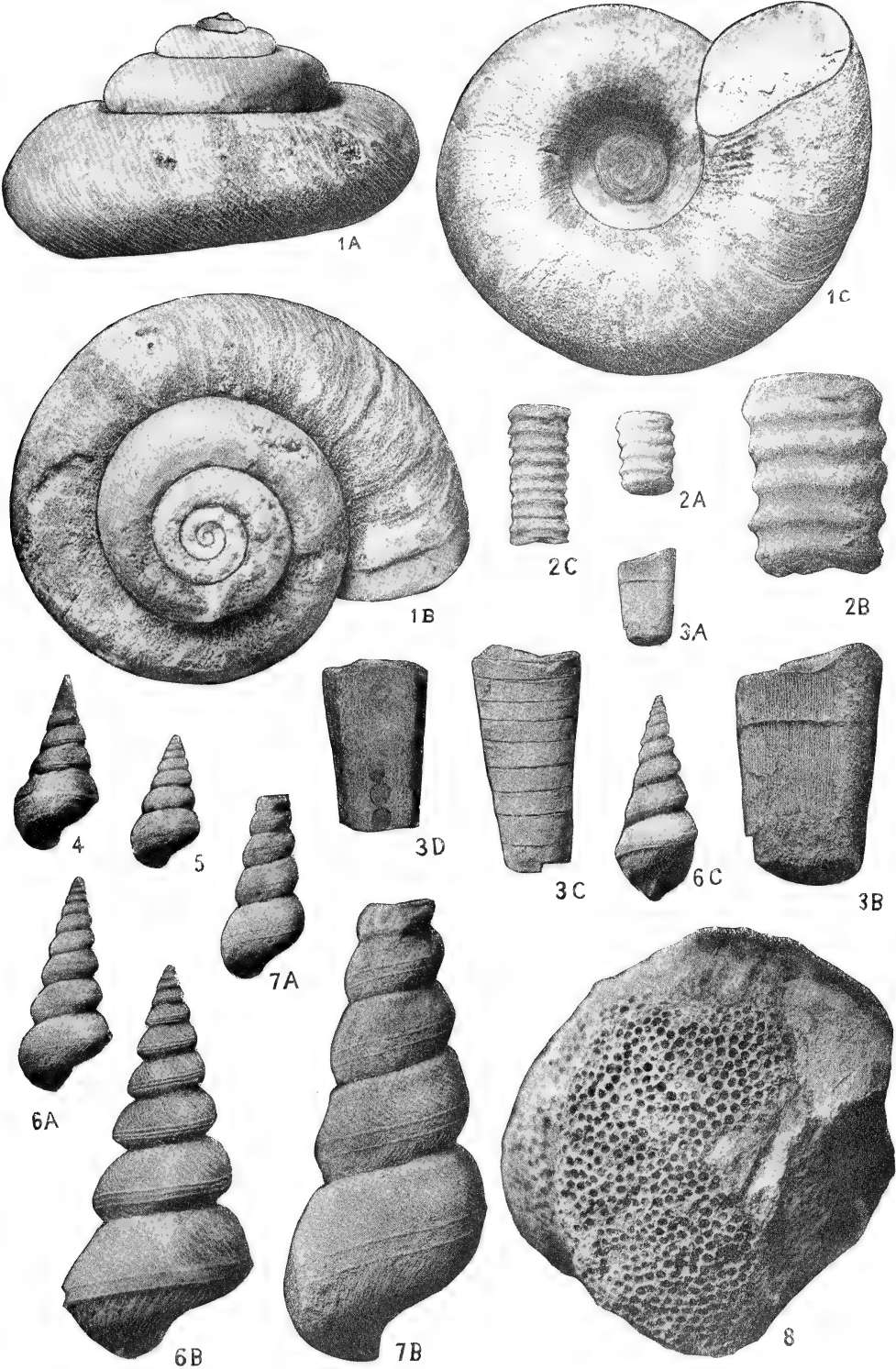


PLATE XV-A

Fig. 1. *Dalmanites* sp. Cranidium with adjacent parts of free cheeks; middle part of anterior outline uncertain. Strongly convex cranidium apparently related to *Dalmanites vigilans* Hall. Cedarville, Ohio; in Cedarville dolomite.

Fig. 2. *Dalmanites* sp. Pygidium associated in same layers with the latter; tip of posterior outline uncertain. Cedarville, Ohio; in Cedarville dolomite.

Fig. 3. *Dalmanites* cf. *Illinoisensis* Weller. Pygidium. Moodie quarry, at Wilmington, Ohio; in the Cedarville dolomite. Collection of Dr. George M. Austin.

Fig. 4. *Cheirurus welleri* Raymond. Hypostoma. Moodie quarry at Wilmington, Ohio; in Cedarville dolomite. Collection of Dr. Charles Welch.

Fig. 5. *Cheirurus welleri* Raymond. Cranidium with posterior part restored. Moodie quarry at Wilmington, Ohio; in Cedarville dolomite. Collection of Dr. Charles Welch.

Fig. 6. *Cypricardinia jepthaensis* Foerste. Right valve. Loose chert, of Laurel age, on Jephtha Knob, Kentucky.

Fig. 7. *Trochonema* sp. Loose chert of Laurel age, on Jephtha Knob, Kentucky.

Fig. 8. *Eccyliomphalus circinatus* (Whiteaves). Apical end of shell with septa. Five-eighths of a mile northeast of Steam Furnace, south of Peebles, Ohio; in strata equivalent to the Guelph formation.

Fig. 9. *Lophospira bucheri* Foerste. Loose chert of Laurel age, on Jephtha Knob, Kentucky.

Fig. 10. *Camarotoechia indianensis* (Hall). A, brachial valve; B, pedicel valve. Loose chert of Laurel age, on Jephtha Knob, Kentucky.

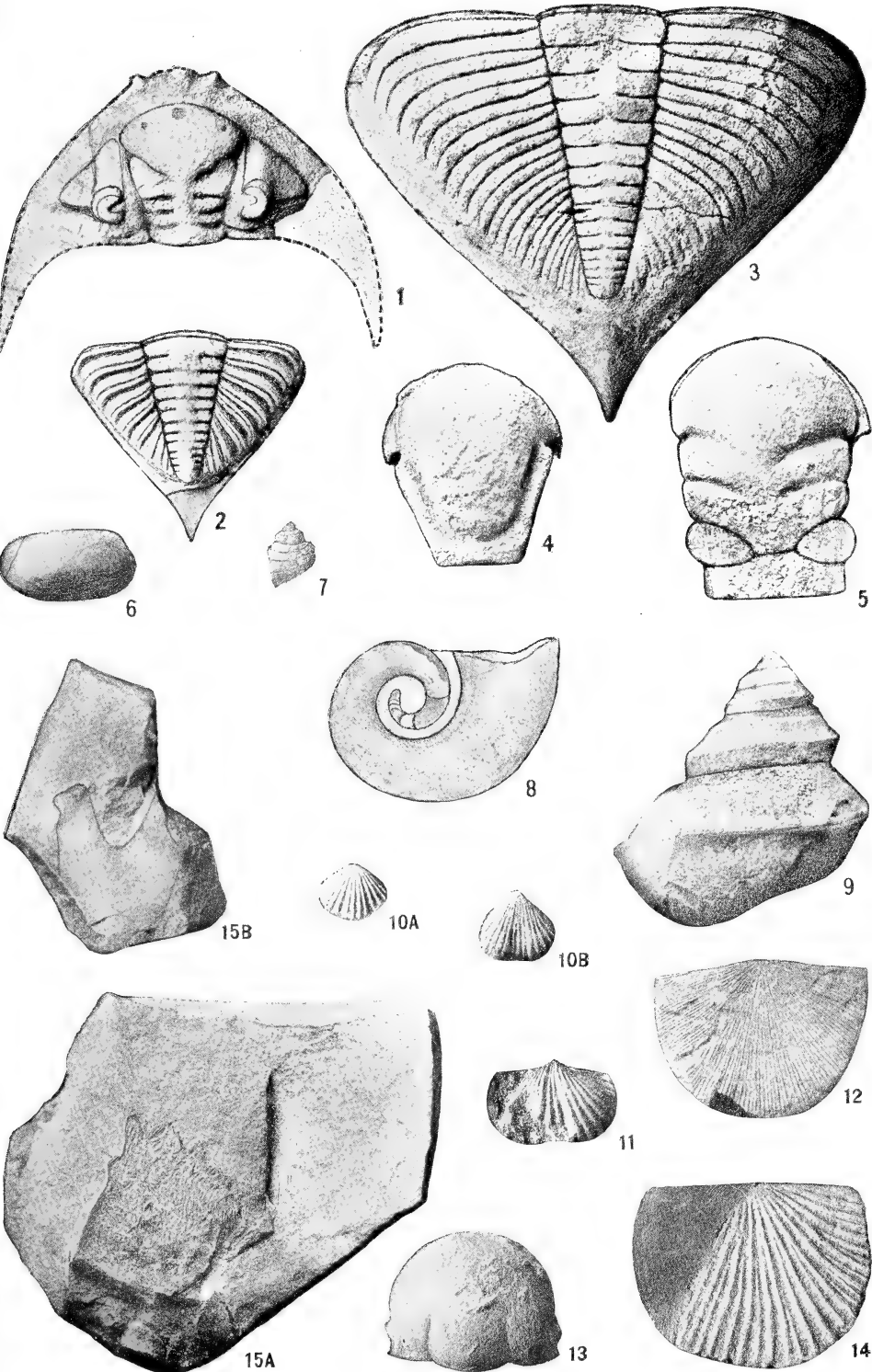
Fig. 11. *Platystrophia daytonensis* (Foerste). Pedicel valve. Loose chert of Laurel age, on Jephtha Knob, Kentucky.

Fig. 12. *Schuchertella* sp. Loose chert of Laurel age, on Jephtha Knob, Kentucky.

Fig. 13. *Illænus* cf. *daytonensis* Hall and Whitfield. Loose chert of Laurel age, on Jephtha Knob, Kentucky.

Fig. 14. *Orthis bucheri* Foerste. Brachial valve. From residual Brassfield limestone at south spur of South Hill, on Jephtha Knob, Kentucky. Named in honor of Dr. Walter H. Bucher.

Fig. 15. *Buthotrephis creditensis* Foerste. A, Type specimen, with fragment of frond. B, lobate portion of another frond. Credit Forks, Ontario; in basal part of Manitoulin dolomite.





## THE EGG AND LARVA OF HESPERIA JUBA BDV.

A. W. LINDSEY

During the last two weeks of June and early in July, 1922, while the writer was collecting in Modoc County, California, *juba* was on the wing in large numbers. The females were much more numerous than the males, and the prospect of adding a life history of this fine species to our scanty knowledge of the early stages of the Hesperioidea seemed good. Most of the specimens collected, however, were taken on the flowers of a small composite which grew on a dry hillside, and no eggs were obtained until June 29, when a female was observed to place one on a blade of grass at the edge of a small irrigation ditch. This was in a hay field, and the grass was so immature that it could not be identified—a matter which proved immaterial, since the larva ate every species offered to it. Only the one egg was secured. It gave promise of furnishing the complete life history, but the necessity of transporting the larva at the end of the season proved fatal. It ate grasses found at Los Angeles, almost 5000 feet lower in altitude than its native region, and passed its fourth moult in that city, but was then attacked by a mold which caused its death.

Little work of a soundly scientific character has been done on the larvae of the Hesperioidea, hence these notes must be regarded as a pioneer attempt to use the results obtained in the study of other lepidopterous larvae. Prominent among such studies are the recent writings of Mr. Carl Heinrich of the National Museum on the larvae of microlepidoptera. An attempt has been made to follow these papers in the study of the head capsules of the *juba* larva, and Heinrich's use of Dyar's system of nomenclature of the primary body setae has also been adopted in preference to the rather elaborate method of Fracker.<sup>1</sup>

<sup>1</sup> Fracker, S. B., Class. Lep. Larvae. 1915.

It is unfortunate that so little material could be preserved for this study, but the complete series of head capsules, the setal map of an abdominal segment of the first instar (fig. 4), sketched in the field, and the maps made from the preserved body in the fifth instar, show some interesting and suggestive things with regard to the possible basis of classification of skipper larvae. It is obvious from the notes recorded that (1) a reduction of primary setae occurs during the first ecdysis, both on head and body, and that (2) it is accompanied by an assumption of a prominent vestiture of secondary setae. The secondary setae of the body have been apparently glandular or sensory in all species observed by the writer. Since the change in vestiture after the first instar agrees with the writer's memory of findings published by Dyar in a paper at present unavailable, it is probably a factor which must be contended with in the entire superfamily, with the possible exception of the Megathymidae and Euschemonidae. The possible persistence of primary setae or tubercles has been pointed out by Fracker,<sup>2</sup> but without any attempt to interpret specific cases. This attempt is made here, although it must necessarily be supported by other observations before it can be more than a suggestion.

The following paragraphs on the egg and larval stages give the writer's field notes, supplemented by measurements of the head capsules. These are followed by a brief discussion of the chaetotaxy of the larva, based, with the exception of the first instar, upon the preserved fifth stage larva and the head capsules.

**Egg:** Deposited June 29, about 2:00 p.m., in a damp sunny place close by the edge of a small irrigation ditch, where the humidity must have been much higher than in the localities frequented by the adults. The egg was circular, its flattened base about 1 mm. in diameter. Its height was about 0.75 mm., the sides rounding up to a flattened micropylar area about 0.4 mm. in diameter. Shell white with a yellowish tinge due to the contents. Surface covered with a fine reticulation of raised lines, plainly visible under an eighteen diameter hand lens, though not at all prominent. On July 7 the micropylar area

<sup>2</sup> Op. cit., p. 127.

showed a small black spot which increased to half the diameter of the egg by the morning of July 9. The larva emerged some time during that day and had eaten all of the free portion of the egg shell when it was observed at 5:00 p.m.

**First Instar:** Newly hatched larva 2.3 mm. long, 0.5 mm. in greatest diameter. Color yellowish white with black setae. First segment brownish with black cervical shield. First pair of legs black, second pair distinctly suffused with blackish and third pair slightly so. It was difficult to make definite observations of the setae with only a hand lens, but the following may be quoted from notes made in the field:

On the anal plate there is a marginal row of six setae, the next to the outermost long (0.3 mm?) and upturned. All others perhaps not over 0.1 mm. long. Against the pale body they appear dark—it is certain, at least, that they arise from tiny dark tubercles—but against the green of a leaf they appear shining and pale, with enlarged whitish tips.

This suggested glandular hairs, but a lens could not verify the point. The setal map (fig. 4) shows the arrangement of the setae of an abdominal segment. It was checked so carefully, even in bright sunlight, that probably nothing was omitted which could be seen under the low magnification available. Diameter of head capsule 0.6 mm.

**Second Instar:** The first stage larva began its moult on July 14 and completed it before the morning of July 16. In the second instar all primary setae excepting the two longest on the anal plate were either lost or obscured by the sparse coat of short, dark secondary setae which had appeared. The skin was yellowish and transparent, the general appearance greenish, due to the contents of the alimentary canal. The head, first segment and thoracic legs were extremely dark brown, almost black; the first segment was marked with a transverse anterior line, whitish in color. Diameter of head 0.8 mm.

**Third Instar:** The second moult began on July 22 and, like the first, was completed before the larva was examined on the morning of the second day thereafter, viz., July 24. In the

third instar the appearance of the larva was much as in the second. Its general color was pale brownish, only slightly tinged with green. The numerous short brown secondary setae were scattered on the anterior third of each segment, and behind this arranged in five or six transverse rows, separated by shallow wrinkles. The setae appeared to have thick pale tips, again suggesting glandular structure. Diameter of head capsule 1.4 mm.

In this stage the larva spun a small cocoon between a blade of grass and the jar in which it was kept, in preparation for its moult, which was begun August 5 and completed before 5:00 p.m., August 6.

**Fourth Instar:** No differences could be noted aside from the increased size. Diameter of head capsule 2 mm.

On the morning of August 16 the larva had spun another cocoon with large open meshes, in which it completed its fourth moult by the morning of August 18. A few days later the ventral surface of the abdomen showed a patch of white fungus, and when this continued to spread the entire larva was placed in alcohol.

**Fifth Instar:** Diameter of head 2.6 mm. The head of the preserved larva appeared in all ways similar to that of the fourth instar, as also did the body. Microscopic examination of the preserved specimen, however, disclosed many details which could not be observed with a hand lens in the field. The skin was found to be roughened with numerous stellate prominences, and the abundant secondary setae proved to be glandular or sensory as supposed. These setae varied roughly in accordance with their position on the body. On the back the short form (fig. 5c) predominated. Ventrad they merged into the form shown by figure 5b, while on the sides of the thorax the intermediate form (fig. 5a) was observed. With regard to the presence of primary setae little can be said which is not amply expressed by the maps in figure 3. The presence of secondary setae of ordinary form on the ventral surface made it impossible to be certain that the prominent setae represented were really primary. The ring-like tubercles, which show their hollow centers

only under relatively high magnification, are conspicuous structures. Whether, as suggested by Fracker and as treated here, they represent primary setae or are an entirely different kind of organ, remains to be proved. In any case they are probably of taxonomic value. The first instar map has aided in the interpretation of the fifth instar setae, but is probably incomplete in the ventral region, due to the low power of the lens used in making it.

In the first instar the head was light brown with sparse rounded punctures on the epicranium. The capsules of the remaining stages, in contrast, were so densely blackish brown that they could not be examined by transmitted light, and the punctures covered the entire epicranium and frons, separated by about their own diameter, and merging into roughened sulci toward the clypeus. The change in form of the head is well represented by figures one and two, showing the first and fourth instars. In the fourth instar a few transparent spots appeared in the epicranium and frons, two, rather long, flanking the frontal suture, two pairs in the frons, and two larger patches in front of the ocelli.

The setae of the head in the first instar (fig. 1) included a pair of ultra posteriors and two pairs of adfrontals, all rather prominent, which could not be observed in the later stages. In these, however, they may possibly have been obscured by the numerous short curved secondary setae which were to be found between the punctures. One ocellar seta likewise was found only in the first instar, but none of the setae of the middle group of the labrum could be discovered in this stage, and only one of the mandibular group.

## PLATE XVI

### LARVA OF *Hesperia juba* Bdv.

Fig. 1 Anterior aspect of head, first instar.

Fig. 2. Anterior aspect of head, fourth instar.

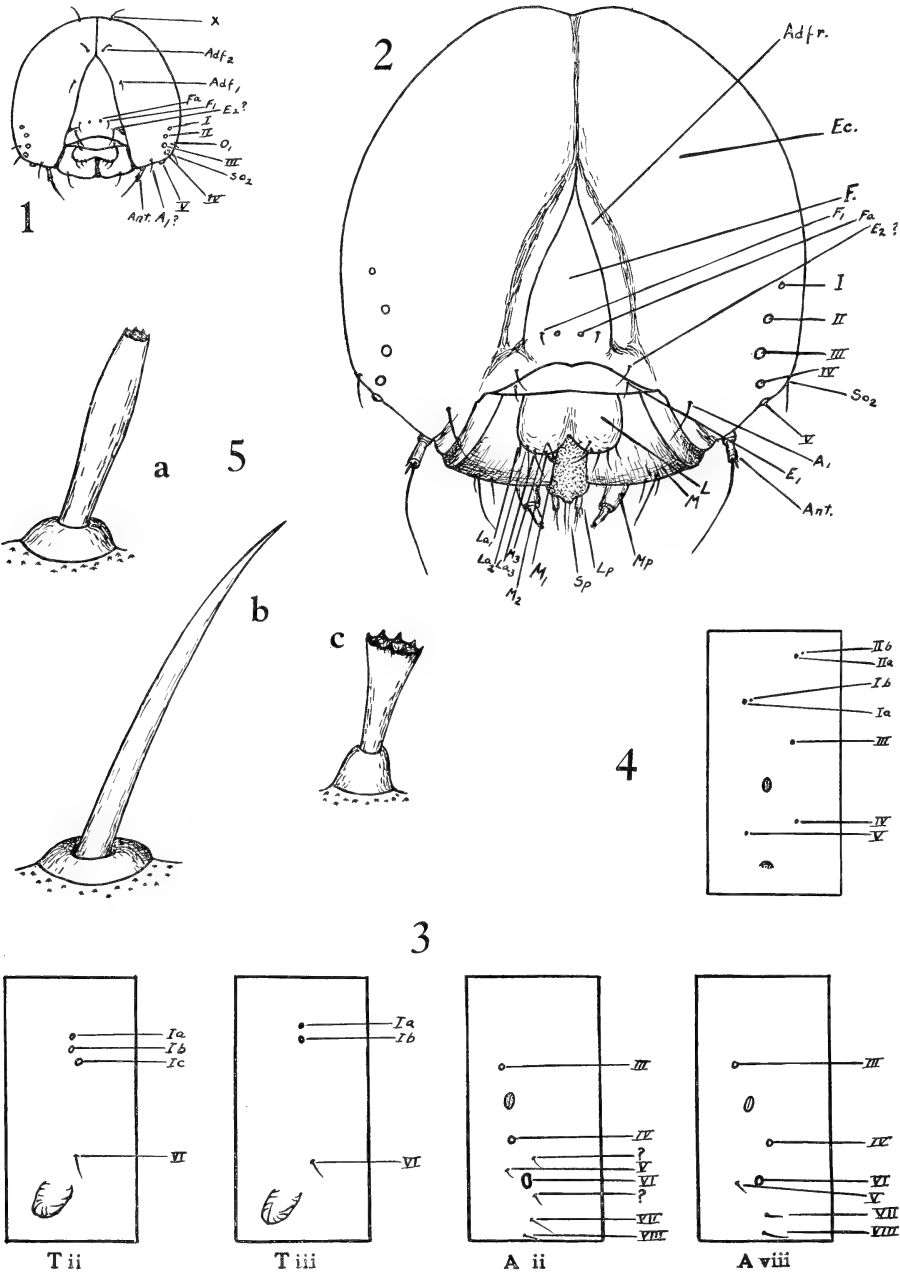
#### *Labels for figures 1 and 2*

- F Frons
- Ec Epicranium
- Adfr Adfrontal ridge and suture
- L Labrum
- M Mandible
- Mp Maxillary palpus
- Lp Labial palpus
- Sp Spinneret
- Ant Antenna
- I, II, III, IV, V Ocelli
- X Ultraposterior seta
- Adf<sub>1</sub>, Adf<sub>2</sub> Adfrontal setae
- Fa Frontal puncture
- F<sub>1</sub> Frontal seta
- E<sub>1</sub>, E<sub>2</sub> Epistomal setae
- O<sub>1</sub> Ocellar seta
- So<sub>2</sub> Subocellar seta
- A<sub>1</sub> Anterior seta
- M<sub>1</sub>, M<sub>2</sub>, M<sub>3</sub> Median setae of labrum
- La<sub>1</sub>, La<sub>2</sub>, La<sub>3</sub> Setae of labrum

Fig. 3. Setal maps, fifth instar. T ii and T iii, second and third thoracic segments. A ii and A viii, second and eighth abdominal segments.

Fig. 4. Setal map of abdominal segment, first instar.

Fig. 5. Secondary setae, fifth instar. a. From ventro-lateral region of thoracic segments. b. From ventral region. c. The most common form, found in lateral and dorsal regions.



A. W. LINDSEY

EGG AND LARVA OF HESPERIA JUBA



## THE OCCULTATION OF VENUS BY THE MOON ON JANUARY 13, 1923

P. BIEFELD

An occultation of Venus, like a total eclipse of the Sun, is not in itself of infrequent occurrence, but for any one place on the earth's surface it is extremely rare. The last one visible in this section of the United States happened early in December of 1878.

At Granville (Swasey Observatory) during the night hours preceding the event the sky was almost completely covered. At about 3:00 a.m., however, the sky cleared completely and Venus shone brilliantly some distance east of the Moon.

Venus was about two weeks past maximum brightness but still about 130 times as bright as Aldebaran, the follower of the Pleiades. The Moon was three and one-half days before "new," showing a slender crescent.

It was a superb sight watching the slow but steady approach of the two objects. Apparently a collision seemed inevitable; but only apparently so. The catastrophe was sure to be avoided; the Moon being only about a quarter million of miles from us, while Venus kept at a safe distance of about 47,000,000 miles. The Moon merely covered up Venus in the line of sight by passing over her on the celestial sphere.

Quite a number of last year's and this year's students of Astronomy being present, no attempt was made to observe accurately with the 9-inch the first and second contacts at immersion and emersion, nor were micrometric measures of these points with reference to the north point attempted. It seemed more practicable for the benefit of the students to demonstrate a photographic method for deriving approximately the time of emersion and duration of occultation from two photographic exposures before and after occultation respectively and from the

observation of the time of immersion by the students and myself. No attempt was made to get first and second contacts noting only the time of immersion of the center of the planet.

To have a check on the work Mr. Bannister, a last year's student of Advanced Practical Astronomy, computed the occultation for Granville. A few statements concerning this are perhaps of interest.

#### THEORY OF OCCULTATIONS

An occultation of a fixed star, approximately an occultation of a planet, may be considered as a special case of an eclipse of the Sun, imagined so far away that its parallax and diameter may be taken equal to zero. Then the cone circumscribing the Sun and Moon in case of a solar eclipse becomes a cylinder in case of a fixed star or planet. The cylindrical shadow cast by the planet shining on the Moon is intercepted by the Earth, or better by a plane passed through the center of the Earth perpendicular to a line passing through the center of the planet and the Moon, and of a linear diameter equal to that of the Moon. The intersection of the fundamental plane with the plane of the Earth's equator plane forms the X-axis of a system of rectangular coördinates of which the Y-axis lying in the same plane points to the north.  $x$  and  $y$  are then the coördinates of the point where the axis of the shadow pierces the fundamental plane, the center of the Earth being the origin;  $x$  and  $y$  being expressed in terms of the radius of the Earth as unity.

The "elements" for the prediction of the occultation as found in the American Ephemeris are then as follows:

$T$ , in G. M. T., is the time at which the planet is in geocentric conjunction in Right Ascension.

$H$  is the geocentric hour angle of the Moon and planet at this time.

$Y$  is the  $y$ -coördinate of the piercing point of the axis of the shadow cylinder with reference to the fundamental plane at that moment.

$x'$  and  $y'$  are the hourly variation in  $x$  and  $y$ .

From these elements, together with the position of the place of the observer and the declination of the planet, the Mean Time of immersion and emersion of the center of the planet, the angles which these points make with the north point and the duration of the occultation may be computed.

## OBSERVATIONS AND MEASUREMENTS

1. A photograph was taken before immersion at time  $T_1$  (point I of fig. 3).

2. Immersion was observed at time  $T_2$  (point E).

3. A photograph was taken after emersion at time  $T_4$ , times  $T_1$ ,  $T_2$ ,  $T_4$  were recorded on the chronograph in Gr. M. T. (Granville mean time).

4. The two negatives were superimposed and a positive made of same size with the reproducing camera.

5. Prints were made of this positive for measuring with a mm. scale to tenths of millimeters. These measurements were afterwards checked with the comparator of the observatory.

*Reductions of observations*

$T_1$ was found to be .....	17 <sup>h</sup> 35 <sup>m</sup> 14.0 <sup>s</sup> (Gr. M. T.)
$T_4$ was found to be .....	18 57 06.0 (Gr. M. T.)
$T_4 - T_1$ was found to be .....	1 21 52.0 = 34.26 mm.
From this was found .....	143.38 = 1 mm.
$T_2$ was found to be (directly observed immersion) .....	17 <sup>h</sup> 53 <sup>m</sup> 45 <sup>s</sup> .0
$T_2 - T_1$ was found to be (from measurement of print) .....	18 13.3
$T_2$ was found to be (from measurement of print) .....	17 53 27.3
$T_4 - T_3$ was found to be (from measurement of print) .....	7 52.9
$T_4 - T_1 - [(T_2 - T_1) + [(T_4 - T_3)]] =$ duration of occultation ....	55 45.8
$T_4 - (T_4 - T_3) = T_3$ (from measurement of print, emersion) .....	18 49 13.1

*Comparison with calculation*

## Time of immersion

Calculated .....

Observed:  $T_2$  .....

From print:  $T_2$  .....

## Time of emersion

Calculated:  $T_3$  .....

From print  $T_3$  .....

Duration of occultation	
Calculated.....	56 23.88
Measured.....	55 45.80
Point of immersion from north point calculated.....	59°59'57"
Point of emersion from north point calculated.....	330 29 52
Measurements with scale.....	1 mm. = 145 <sup>s</sup> 3
Measurements with comparator.....	1 mm. = 143. 38

## PLATE XVII.

- Fig. 1. Photograph taken at time  $T_1$ .  
 Fig. 2. Photograph taken at time  $T_2$ .  
 Fig. 3. Diagram of two photographs superimposed.



Fig. 1

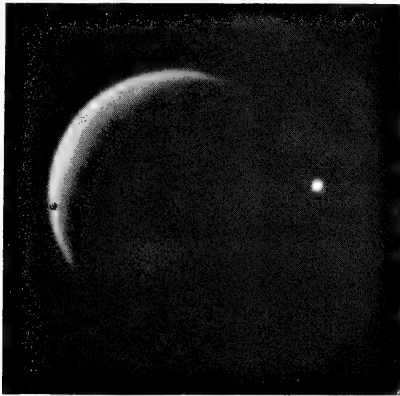


Fig. 2

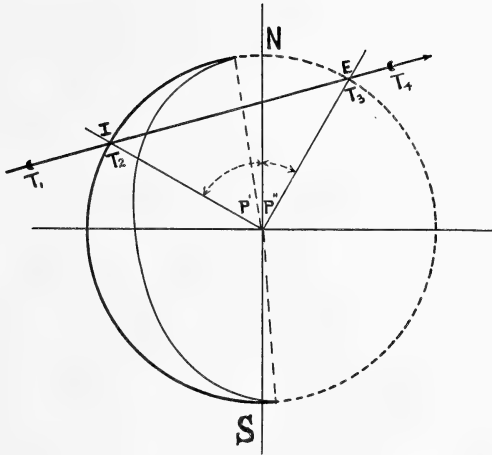


Fig. 3

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OCCULTATION OF VENUS BY MOON



# A BOTANICAL SURVEY OF THE CAMPUS OF DENISON UNIVERSITY<sup>1</sup>

DWIGHT MUNSON MOORE

## INTRODUCTION

*General location.* The campus of Denison University is one of the most attractive spots in the state of Ohio. The greater part of it is on a hill at the northern margin of the village of Granville, situated near the center of Licking County, close to the geographic center of the state. Recent additions to the campus have increased its area to approximately 350 acres. Of this, Shepardson College occupies about one acre, Granville College about fifty acres, and the remainder composes Deeds Field, a great recreation and athletic field, and the College Farm.

*Scope of this paper.* The present study is limited to the phanerogams of that part of the campus bounded by Burg street on the west, College street on the south, Mulberry street and its northward extension on the east, and the northern edge of the College woods, hereafter called the North Woods, on the north. It is hoped that the paper may later be supplemented with a study of the rest of the campus.

*Geology and physiography.* The region is near the western edge of the Allegheny Plateau, within the zone of transition between the maturely dissected upland occupying the greater part of southeastern Ohio and the undulating lowland of central western Ohio. One of many hills of a rolling upland, intersected by streams, has been chosen for the campus. Its summit rises slightly above 1100 feet in altitude, and overlooks the broad flat-floored valley of Raccoon Creek which flows eastward along the southern foot of the hill at an elevation of about 900 feet

<sup>1</sup>Contribution from the Botanical Laboratory of Denison University, No. XIII.

above the sea. The north slope of College Hill is much shorter and more abrupt than the principal south slope.

The rocks underlying the region are indicated in the accompanying diagram (fig. 1). All belong to the Waverly Series, of Mississippian age, and are grouped by geologists into two formations, the Logan and Cuyahoga, each comprising several members. The top of College Hill is composed of a rather coarse sandy shale or sandstone, the Allensville member of the Logan formation. Beneath this, and outcropping near the west margin of the campus at the "Biological Pool" is the Byer sand-

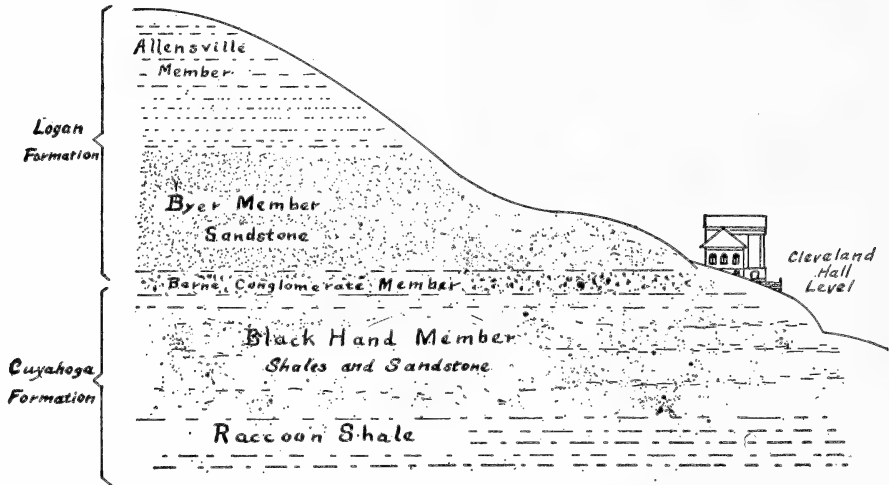


FIG. 1. DIAGRAM SHOWING GEOLOGIC STRUCTURE OF COLLEGE HILL

stone, a freestone which has been quarried at several places on the higher slopes of the hill. The Berne conglomerate beneath the Byer marks the division between the two formations, named above. It is a rather inconspicuous bed, 6 to 18 inches thick, composed of clean quartz pebbles in a sandy matrix. The Black Hand and Raccoon members of the Cuyahoga are sandstones interspersed with sandy shales of quite variable thickness and composition.

All of these on weathering produce a rather loose and more or less sandy soil which is found on the greater part of the campus. Where shales predominate, however, there is a stiffer clay

soil which in places packs hard and is unfavorable for the growth of many plants. The entire region has been covered at least twice by ice sheets which left a thin and scattered deposit of glacial drift. In consequence the surface is quite gravelly at many places.

*Climatology.* The data for this topic have been taken more or less completely from a report compiled by J. Warren Smith, covering the climate and weather in south central Ohio, in the general summary of climatological data for the United States. No records have been made in this area by the writer, but the data for Columbus, 28 miles distant, extend from 1878 and these have been used.

The monthly mean temperatures in degrees Fahrenheit and and the average monthly rainfall in inches at Columbus are as follows:

	MONTHLY MEAN TEMPERATURES (31 YEARS OF RECORDS)	AVERAGE MONTHLY RAINFALL (30 YEARS OF RECORDS)
January.....	28.9	2.97
February.....	30.1	3.01
March.....	39.6	3.49
April.....	51.1	2.84
May.....	62.5	3.80
June.....	71.0	3.41
July.....	75.2	3.65
August.....	72.7	3.21
September.....	66.9	2.41
October.....	54.7	2.32
November.....	41.8	2.91
December.....	32.7	2.66
Annual.....	52.2	36.68
Growing season.....	66.6	

The absolute extremes of temperature for the central part of Ohio are 108° and -34°. These are important because of their possible effect in limiting the growth of vegetation, tending to control the northern limits of many species.

The average date of the last killing frost in spring is April 30, of the first killing frost in the autumn, Oct. 2. The average growing season is therefore about 155 days in length. However, the minimum growing season is about 110 days. "Precipitation is quite uniform over the whole section (in which our area is located) and averages about 38 inches per year." "In general there is the greatest average rainfall in June and July and the least in October."



FIG. 2. THE NORTH WOOD IN EARLY SPRING, SHOWING NATURE OF UNDERGROWTH

#### ECOLOGY

The natural growth of vegetation has been changed for ornamental purposes, except that of the north hillside, which is almost a virgin forest. The area thus may be divided into wooded areas and open tracts. Among the first there are two: the North or College Wood (I) and the West Wood (II). Of the open tracts four may be distinguished, viz.: the West campus (III), South hillside (IV), East campus (V) including south-east hillside, and the central campus (VI).

*The wooded areas*

I. The College Wood is a typical mesophytic wood, principally of beech, maple, elm, ash, and only a few oak trees. This might be termed a moist wood. The forest floor presents an excellent example of seasonal plant succession. In April the floor is almost entirely covered with the two *Dicentras*, and *Dentaria lacinata*, with a generous sprinkling of *Viola cucullata*



FIG. 3. THE FLOOR OF COLLEGE WOOD IN SPRING, SHOWING HYDROPHYLLUM, GALIUM AND THE DICENTRAS

and *pubescens*. All of these are quite low forms which must complete their short period of photosynthetic work before other larger plants overshadow them.

In May there is a greater profusion of *Hydrophyllum* and *Chelidonium* with *Galium aparine* pushing upward. Late in May and early June these have mostly given way to *Impatiens biflora* and various other scattered taller forms.

Later in the summer these forms have given place to various Asters, especially *Aster cordifolius*, and to *Eupatorium urticaefolium*.

This wood presents a good illustration of forest succession. The majority of the trees are beech and maple, while the oaks and chestnut appear to be among the oldest. But among the young trees coming on there are almost no oaks, chestnut, or hickory while there is an abundance of maples, beech, elms, and wild cherry. This clearly shows that the oaks, hickories and chest-



FIG. 4. THE NORTH WOOD, WITH A DENSE GROWTH OF HYDROPHYLLUM

nuts are losing ground and will all disappear within the coming generation, giving place entirely to the others which are dominant among the seedlings.

Recently an effort has been made to save some of the older beeches which have become hollow, by the application of tree surgery. This seems to have been successful in several cases.

Another recent introduction in this wood is the building of a Greek temple which serves as the background for the stage of an outdoor theater in the center of the wood. Naturally the use of the wood for this purpose will have a serious effect upon

the plant forms which happen to be in their period of flower at the time the amphitheater is used. But this may not be great if its use is not carried too far.

II. In the West Wood, the trees are much the same, with the beech most abundant then the sugar maple, elms, black walnut, and wild cherry making up the most of the remainder. Here is noticed, even more than in the North Wood, that it is the beech and maple that make up the majority of the young



FIG. 5. THE WEST WOOD

trees. Thus this wood will continue to be a beech-maple association through the next generation.

The soil here is much drier, due probably to the southern exposure, a more open wood, and the fact that the soil is thinner over the underlying strata of rock.

Owing to the moisture conditions, the ground flora is more limited than in the North Wood. Here are found principally *Sanguinaria canadensis*, *Podophyllum peltatum*, *Clatonia virginica*; various species of *Geum*, *Galium*, *Desmodium*, and *Carex*;

also *Bidens bipinnata*, *Rubus allegheniensis*, and *Solidago caesia*. It is quite interesting to note the entire absence here of the *Hydrophyllum* and the *Dicentras* which are so profuse in the North Wood.

III. Of the open tracts the west section is perhaps the driest. There are several trees scattered over the larger part of it, and west of the library these are numerous enough to make it quite shaded. The prominent trees are *Fagus grandifolia*, *Fraxinus americana*, *Ulmus americana* and *fulva*, and *Acer saccharum*. Of the herbaceous plants the most prominent are:

Andropogon virginicus	Dactylis glomerata
Danthonia spicata	Erigeron annuus
Poa compressa	Erigeron philadelphicus
Poa pratensis	Capsella Bursa-pastoris
Juncus tenuis	

IV. The south hillside has the flora of an open meadow and includes several grasses and others:

Achillea millefolium	Lactuca scariola
Ambrosia artemisiifolia	Poa pratensis
Asclepias syriaca	Ranunculus abortivus
Daucus carota	Rumex acetosella
Dactylis glomerata	Rumex crispus
Erigeron annuus	Rumex obtusifolius
Erigeron philadelphicus	Saponaria officinalis
Galium aparine	Solidago rugosa
Galium concinnum	Solidago serotina
Hypericum mutilum	

However at the foot of the hill, a line of Spruce trees casts such a shade that there are but a few forms, especially *Galium aparine*, *Geum vernum*, *Menispermum canadense*, *Psedera quinquefolia*, *Ranunculus abortivus*.

But taken as a whole the south hillside has the widest variety of any group studied. This appears to be due to the abundant sunlight and rather moist soil, brought about by a "springy" condition of the underlying rock strata. Also the fact that this receives very little attention during the year—it being mowed not more than twice in the twelve-month—permits the introduction, growth and fruiting of many new and varied forms.

Among the trees that may be mentioned are only such as have been planted for ornamental purposes. There are found here the following: Scotch Pine, Norway Spruces, Kentucky Coffee Tree, Norway and Silver Maples, Japan Maple, Osage Orange.



FIG. 6. THE SLOPE OF THE CENTRAL CAMPUS FROM THE HILLTOP TOWARD THE SOUTH PLAZA

V. The east hillside and campus are quite similar to the south hillside in most respects. The slope is probably more abrupt at first, becoming more nearly level lower down.

The trees that have been planted on this slope are:

*Alnus glutinosa*  
*Betula Alba*  
*Chionanthus virginica*  
*Corylus avelana*

*Betula populifolia*  
*Cercis canadensis*  
*Morus rubra*  
*Platanus occidentalis*

VI. The central campus has the constant attention of a caretaker, and for the greater part is carefully mowed as often as once a week. This practice has reduced the number of forms to only those which are naturally low or can adjust themselves to these conditions. Here we find principally:

<i>Agrostis alba</i>	<i>Stellaria media</i>
<i>Cerastium vulgatum</i>	<i>Taraxacum officinale</i>
<i>Plantago lanceolatus</i>	<i>Veronica arvensis</i>
<i>Plantago major</i>	<i>Veronica serpyllifolia</i>
<i>Poa pratensis</i>	
<i>Prunella vulgaris</i>	

In this area also have been planted such shrubs and trees as

<i>Acer rubrum</i>	<i>Crataegus Crus-galli</i>
<i>Acer saccharum</i>	<i>Ulmus americana</i>
<i>Aralia spinosa</i>	<i>Ulmus fulva</i>

Artificial grouping has been carried out around all the buildings and at the principal entrances. The accompanying views of the east entrance show the masses of *Kerria*, *Rosa*, *Rhodotypos*, *Forsythia* and *Symphoricarpos*.

Around the buildings are found a number of species of *Deutzia*, and *Spirea*, as well as *Berberis*, *Forsythia*, *Kerria*, *Lonicera*, *Philadelphus*, *Symphoricarpos*. These introduced species are bunched and so selected that there are some of them in flower from the opening of the *Forsythia* in April through the roses in the summer and leaving the attractive white berries of *Symphoricarpos* in the fall.

#### FLORA

In making the study of the flora of the campus, the writer found it necessary to start from the beginning as there was absolutely no record of any plants of this particular region.

No effort has been made to make a complete collection of the various forms found, but when any were found which the herbarium of the University did not contain, they were added to it.

Verification of the identification of the plants given below in the list has been made by reference to and comparison with the herbarium of the department of Botany of Denison University.

The nomenclature used is that of Gray's *New Manual of Botany*, 7th Edition, except in the case of the exotics which are



FIG. 7. THE CAMPUS ON THE HILL

not included in the *Manual*. In these cases Gray's *Field, Forest and Garden Botany* and Bailey's *Cyclopedia of American Horticulture* have been used. Britton and Brown's *Illustrated Flora of the Northern States and Canada* has been freely used in the identification of the plants.

The Flora as follows is listed in the order given in the *Check list of the plants found in Gray's Manual*, published by the Gray

Herbarium of Harvard University. Such plants as are quite evidently not growing in their natural habitat or have been set out on the campus are printed in italics.

## GYMNOSPERMAE

Ginkgoaceae—Ginko Family.

*Ginkgo biloba* L. Maiden-hair tree. Back of Marsh Hall.

Pinaceae—Pine Family.

*Abies concolor* Lindl. White fir. IV.

*Juniperus Virginiana* L. Red cedar. IV, and a few scattered seedlings.

*Picea abies* (L.) Karst. Norway spruce. II, IV, V.

*Pinus strobus* L. White pine. One small tree behind Cleveland Hall.

*Pinus sylvestris* L. Scotch Pine. I, IV.

*Taxodium distichum* (L.) Richard. Bald cypress. Behind Marsh Hall.

*Thuja occidentalis* L. Arbor vitae, White cedar. Near Cleveland Hall and near entrances.

## ANGIOSPERMAE

Graminae—Grass Family.

*Agropyron repens* (L.) Beauv. Couch grass. III.

*Agrostis alba* L. Red top. General in III, IV, V, VI.

*Andropogon virginicus* L. Virginia beardgrass. III, V.

*Bromus ciliatus* L. Fringed brome-grass. I.

*Dactylis glomerata* L. Orchard grass. III, IV, V.

*Danthonia spicata* (L.) Beauv. Wild oat-grass. III, IV, V.

*Digitaria sanguinalis* (L.) Scop. Crab grass. IV.

*Eragrostis megastachya* (Koeler) Link. Stink-grass. V.

*Eragrostis pilosa* (L.) Beauv. (Jones.)

*Festuca nutans* Speng. Nodding fescue grass. I.

*Koeleria cristata* (L.) Pers. Koleria. VI.

*Lolium perenne* L. Darnel. IV.

*Muhlenbergia Schreberi* J. F. Gmel. Nimble-Will; Drop-seed grass. I.

*Panicum capillare* L. Witch grass. IV.

*Panicum dichotomum* L. Forked panic-grass. III, IV.

*Phleum pratense* L. Timothy. III, IV, V.

*Poa annua* L. Low speargrass. III, IV, V.

*Poa compressa* L. Wire grass; English blue-grass. III, IV, V.

*Poa pratensis* L. Kentucky blue-grass. III, IV, V.

*Secale cereale* L. Rye. III.

*Setaria glauca* (L.) Beauv. III, IV.

*Setaria viridis* (L.) Beauv. III, IV, V.

*Triticum sativum* L. Wheat. III.

Cyperaceae—Sedge Family.

*Carex cephaloidea* Dewey. Thin leaved sedge. IV.

*Carex digitalis* Willd. Slender wood sedge. II.

*Carex granularis* Muhl. Meadow sedge. III, IV.

*Carex laxiflora* Lam. Loose-flowered sedge. I, II.

*Carex laxiflora* var. *latifolia* Boott. White bear sedge.  
I, II.

*Carex plantaginea* Lam. (Jones.)

*Carex rosea* Schkuhr. Yellow sedge. II.

*Carex Shortiana* Dewey. Short's sedge. Edge of I.

*Carex straminea* Willd. Straw sedge. IV.

*Carex triceps* Michx. Hirsute sedge. IV.

*Carex vulpinoidea* Michx. Fox sedge. IV.

Araceae—Arum Family.

*Arisaema triphyllum* (L.) Schott. Indian turnip. I, II.

Juncaceae—Rush Family.

*Juncus tenuis* Willd. Slender yard rush. III.

Liliaceae—Lily Family.

*Asparagus officinalis* L. Garden asparagus. III, IV.

*Medeola virginiana* L. Indian cucumber-root. II.

*Ornithogalum umbellatum* L. Star of Bethlehem. V.

*Polygonatum biflorum* (Walt) Ell. Small Solomon's Seal. II.

*Polygonatum commutatum* (R & S) Dietr. Great Solomon's  
seal. II.

*Smilacina racemosa* (L.) Desf. False spikenard. II.

*Smilax herbacea* L. Carrion flower. I.

*Smilax rotundifolia* L. Greenbrier. I, II.

*Tulipa gesneriana* L. Common tulip. Near Marsh Hall.

*Uvularia perfoliata* L. Mealy bellwort. I.

*Yucca filimentosa* L. Yucca. IV.

Dioscoreaceae—Yam Family.

*Dioscorea villosa*. Wild Yam-root. I.

Iridaceae—Iris Family.

*Sisyrinchium gramineum* Curtis. Blue-eyed grass.

## Orchidaceae—Orchid Family.

*Orchis spectabilis* L. Showy orchid. I.*Spiranthes gracilis* (Bigel) Beck. (Jones.)

## Salicaceae—Willow Family.

*Populus alba* L. Silver leaved poplar. III.*Populus deltoides* Marsh. Cotton-wood. V.*Salix discolor* Muhl. Pussy willow. Talbot Hall.

## Juglandaceae—Walnut Family.

*Carya cordiformis* (Wang) K. Koch. Bitternut. I, II.*Carya ovata* (Mill) K. Koch. Shellbark hickory. I, II.*Juglans cinerea* L. Butternut; White walnut. II.*Juglans nigra* L. Black walnut. I, II, III, V.

## Betulaceae—Birch Family.

*Alnus glutinosa* L. European alder. V.*Betula alba* L. Cut-leaved weeping birch. V.*Betula populifolia* Marsh. White birch. V.*Corylus avellana* L. European hazelnut. V.*Ostrya virginiana* (Mill) K. Koch. American hop-hornbeam. IV.

## Fagaceae—Beech Family.

*Castanea dentata* (Marsh) Borkh. Chestnut. I, II.*Fagus grandifolia* Ehrh. Beech. I, II, III.*Quercus alba* L. White Oak. I, II.*Quercus bicolor* Willd. Swamp white oak. III.*Quercus coccinea* Muench. Scarlet oak. II, III.*Quercus macrocarpa* Michx. Burr oak. III.*Quercus pedunculata* Ehrh. English oak. III.*Quercus Prinus* L. Chestnut oak. III.*Quercus rubra* L. Red oak. III.

## Urticaceae—Nettle Family.

*Celtis occidentalis* L. Hackberry. I, II, V.*Humulus lupulus* L. Hop vine. IV, V.*Laportea canadensis* (L.) Gaud. Wood nettle. I.*Maclura pomifera* (Raf.) Schneider. Osage orange. IV.*Morus rubra* L. Red mulberry. I, V, VI.*Parietaria pennsylvanica* Muhl. Pennsylvania pellitory. I, II.*Pilea pumila* (L.) Gray. Rich weed; clear weed. I, II.*Ulmus americana* L. White elm. I, II, III, IV, V, VI.*Ulmus fulva* Michx. Red elm. I, II, VI.

## Polygonaceae—Buckwheat Family.

*Polygonum aviculare* L. Knot-grass; door weed. IV, V, VI.

- Polygonum Convolvulus** L. Black bindweed. IV, V  
**Polygonum Persicaria** L. Lady's thumb. I.  
**Rumex acetosella** L. Sheep sorrel. III, IV, V.  
**Rumex crispus** L. Curly dock. III, IV, V.  
**Rumex obtusifolius** L. Yellow dock. III, IV, V.  
Phytolaccaceae—Pokeweed Family.  
**Phytolacca decandra** L. Pokeweed. V.  
Illecebraceae—Knotwort Family.  
**Anychia canadensis** (L.) B.S.P. Forked chickweed. I, II.  
Caryophyllaceae—Pink Family.  
**Agrostemma Githago** L. Corn cockle. IV.  
**Arenaria serpyllifolia** L. Thyme-leaved sandwort. V.  
**Cerastium vulgatum** L. Mouse-ear chickweed. General.  
**Saponaria ociffinalis** L. Bouncing Bet. IV.  
**Stellaria media** (L.) Cyrill. Common chickweed. General.  
Portulacaceae—Purslane Family.  
**Claytonia virginica** L. Spring beauty. II, III, VI.  
Ranunculaceae—Crowfoot Family.  
**Actaea alba** (L.) Mill. White baneberry. I.  
**Anemonella thalictroides** (L.) Spach. Wind flower. I, II.  
**Cimicifuga racemosa** (L.) Nutt. Black cohosh. I.  
**Clematis virginiana** L. Virgin's bower. III, IV.  
**Hepatica triloba** Chaix. Round lobed hepatica. I.  
**Ranunculus abortivus** L. Small flowered crowfoot. General.  
**Ranunculus acris** L. Tall crowfoot. One plant in 1914. VI.  
**Ranunculus repens** L. Creeping buttercup. I.  
Magnoliaceae—Magnolia Family.  
**Liriodendron tulipifera** L. Tulip tree. II.  
Calycanthaceae—Calycanthus Family.  
*Calycanthus floridus* L. Strawberry shrub. IV.  
Anonaceae—Custard Apple Family.  
**Asimina triloba** Dunal. Common Papaw. I.  
Menispermaceae—Moonseed Family.  
**Menispermum canadense** L. Moonseed vine. II, IV.  
Berberidaceae—Barberry Family.  
*Berberis aquifolium* Pursh. Mahonia. East end of Talbot Hall.  
*Berberis vulgaris* L. European barberry. V.  
*Berberis Thunbergii* DC. Japanese barberry. Entrances.  
**Caulophyllum thalictroides** (L.) Michx. Blue cohosh. I.  
**Podophyllum peltatum** L. Mayapple. I, II.

Lauraceae—Laurel Family.

**Benzoin aestivale** (L.) Nees. Spicebush. I.

Papaveraceae—Poppy Family.

**Chelidonium majus** L. Celandine. I.

**Sanguinaria canadensis** L. Bloodroot. I, II.

Fumariaceae—Fumitory Family.

**Dicentra canadensis** (Goldie) Walp. Squirrel corn. I.

**Dicentra Cucullaria** (L.) Bernh. Dutchman's breeches. I.

Cruiferae—Mustard Family.

**Barbarea stricta** Andr. Winter cress. II, III.

**Barbarea vulgaris** R. Br. Yellow rocket. I.

**Capsella Bursa-pastoris** (L.) Medic. Shepherds' purse.  
General.

**Cardamine bulbosa** (Schreb.) B. S. P. Spring cress. I.

**Dentaria lacinata** Muhl. Toothwort. I.

**Draba verna** L. Whitlow grass. VI.

**Lepidium virginicum** L. Wild peppergrass. I, II, III, IV,  
V, VI.

**Sisymbrium officinale** (L.) Scop. Hedge mustard. III,  
IV, V.

Crassulaceae—Orpine Family.

**Sedum ternatum** Michx. Stonecrop. I.

Saxifragaceae—Saxifrage Family.

**Deutzia scabra** Thunb. Deutzia. Around buildings.

**Philadelphus coronarius** L. Mock orange; syringa. Same.

**Ribes Cynosbati** L. Wild gooseberry. I.

**Saxifraga virginensis** Michx. Early saxifrage. II.

Platanaceae—Plane tree Family.

**Platanus occidentalis** L. Sycamore tree. V.

Rosaceae—Rose Family.

**Agrimonia gryposepala** Wallr. Tall hairy agrimony. II.

**Crataegus Crus-galli** L. Cockspur thorn. VI.

**Crataegus punctata** Jacq. Large-fruited thorn. II.

**Fragaria virginiana** Duchesne. Strawberry. II, IV, V.

**Geum canadense** Jacq. White avens. II.

**Geum vernum** (Raf.) T & G. Spring avens. I, II, III.

**Kerria Japonica** DC. Japanese Rose. Entrances.

**Potentilla argentea** L. Silvery cinquefoil. III.

**Potentilla canadensis** L. Fivefinger. II, III, IV.

- Prunus americana** Marsh. Wild plum. II.  
*Prunus avium* L. Sweet cherry. IV.  
**Prunus serotina** Ehrh. Wild black cherry. I, II, III, IV, V.  
*Pyrus Aucuparia* Ehrh. European mountain ash. III.  
*Pyrus communis* L. Pear. III.  
*Pyrus Japonica* Thunb. Japanese Quince. VI.  
*Pyrus malus* L. Apple. III, IV, V.  
*Rhodotypos kerrioides* Sieb. False Kerria. Entrances.  
*Rosa multiflora* Thunb. Rambler rose. Entrances and V.  
*Rosa rubiginosa* L. Sweetbrier. V.  
*Rosa Rugosa* Thunb. Entrances.  
*Rosa setigera* Michx. Prairie rose. Entrances.  
*Rosa wichuraiana* Crepin. Memorial rose. Entrances.  
**Rubus allegheniensis** Porter. Blackberry. I, II, III, V.  
**Rubus occidentalis** L. Black raspberry. I, II, III, V.  
*Rubus odoratus* L. Purple-flowering raspberry. East entrance.  
**Rubus villosus** Ait. Dewberry. III.  
*Spiraea bumalda* Burvenich; var. *Anthony Waterer*. Crimson Spivea. Marsh.  
*Spiraea Douglassi* Hook. Douglas' Meadowsweet. Near buildings.  
*Spiraea Thunbergii* Sieb. Snow Garland. Marsh Hall.  
*Spiraea Van Houttei* Zabel. Bridal wreath. Abundant along drives.

Leguminosae—Pulse Family.

- Amorpha fruticosa* L. False indigo. V.  
**Amphicarpa monoica** (L.) Ell. Hog peanut. I.  
*Cercis canadensis* L. Redbud. V.  
**Cladrastis lutea** (Michx. f.) Koch. Yellow wood. I.  
**Desmodium canescens** (L.) DC. Hoary tick-trefoil. I, II, III, IV, V.  
**Desmodium grandiflorum** (Walt.) DC. Pointed-leaved tick-trefoil. I, II.  
**Gleditsia triacanthos** L. Honey locust. II, III.  
*Gymnocladus dioica* (L.) Koch. Kentucky coffee tree. I, IV.  
**Melilotus alba** Desr. White sweet clover. III, IV, V.  
**Robinia Pseudo-Acacia** L. Black locust. II, V.  
**Trifolium hybridum** L. Alsike clover. III, IV, V.  
**Trifolium pratense** L. Red clover. II, III, IV, V.

- Trifolium procumbens** L. Yellow hop-clover. III, IV, V, VI.  
**Trifolium repens** L. White clover. General in the open.
- Oxalidaceae—Wood sorrel Family.  
**Oxalis stricta** L. Yellow wood sorrel. General.  
**Oxalis violacea** L. Violet wood sorrel. I.
- Geraniaceae—Geranium Family.  
**Geranium maculatum** L. Cranesbill. I, II.
- Euphorbiaceae—Spurge Family.  
**Acalypha virginica** L. Three-seeded mercury. General in shade.  
**Euphorbia maculata** L. Spotted spurge. South hill.
- Anacardiaceae—Cashew Family.  
**Rhus copallina** L. Dwarf sumac. IV.  
**Rhus cotinus** L. Smoke tree. V, VI.  
**Rhus glabra** L. Smooth sumac. II, III.  
**Rhus Toxicodendron** L. Poison ivy. I, II, III, IV.
- Celastraceae—Staff tree Family.  
**Celastrus scandens** L. Bittersweet, Wax work. I, II, III.  
**Evonymus atropurpureus** Jacq. Wahoo. II, VI.  
**Evonymus radicans** Sieb. Jap. spindle bush. Entrance and south plaza.
- Staphyleaceae—Bladdernut Family.  
**Staphylea trifolia** L. American bladdernut. I.
- Aceraceae—Maple Family.  
**Acer Ginnala** Max. Tartarian maple. VI.  
**Acer negundo** L. Box elder. II, IV, V.  
**Acer palmatum** Thunb. Japanese Maple. IV.  
**Acer palmatum** var. *ornatum*, Carr. Cut-leaved Japanese Maple. IV.  
**Acer palmatum** var. *reticulatum*, André. IV.  
**Acer platanoides** L. Norway maple. Two forms. IV.  
**Acer rubrum** L. Red maple. VI.  
**Acer saccharinum** L. Silver maple. III, IV, VI.  
**Acer saccharum** Marsh. Sugar maple. I, II, III, VI.
- Sapindaceae—Soapberry Family.  
**Aesculus glabra** Willd. Ohio buckeye. I.  
**Aesculus Hippocastanum** L. Horse chestnut. V.
- Balsaminaceae—Touch-me-not Family.  
**Impatiens biflora** Walt. Jewel weed. I.  
**Impatiens pallida** Nutt. Pale touch-me-not. I.

Rhamnaceae—Buckthorn Family.

*Rhamnus cathartica* L. Common buckthorn. V.

Vitaceae—Vine Family.

*Ampelopsis tricuspidata* Sieb. & Zucc. Boston ivy. On buildings.

*Psedera quinquefolia* (L.) Greene. Woodbine ivy. I, II, VI.

*Vitis vulpina* L. Frost grape. I, II.

Tiliaceae—Linden Family.

*Tilia americana* L. Basswood; Linden. I, II.

*Tilia heterophylla* Vent. White basswood. III.

Malvaceae—Mallow Family.

*Althaea rosea* Cav. Hollyhock. IV.

*Hibiscus syriacus* L. Shrubby althea. VI.

*Malva rotundifolia* L. Common mallow, Cheeses. III, IV, V, VI.

Hypericaceae—St. John's-wort Family.

*Hypericum punctatum* Lam. Spotted St. John's-wort. II, IV, V.

*Hypericum mutilum* L. Small flowered St. John's-wort. IV, V.

Violaceae—Violet Family.

*Viola papilionacea* Pursh. Common blue violet. General.

*Viola pubescens* Ait. Downy yellow violet. I, II.

*Viola rostrata* Pursh. Long-spurred violet. I.

Elaeagnaceae—Oleaster Family.

*Elaeagnus argentea* Pursh. Silver berry. V.

*Elaeagnus angustifolius* (L.) var. *Spinosa*, Dipp. Oleaster. East entrance.

Onagraceae—Evening Primrose Family.

*Circaea lutetiana* L. Enchanter's nightshade. I, II.

*Oenothera biennis* L. Common evening primrose. III, IV, V.

Araliaceae—Ginseng Family.

*Aralia racemosa* L. Spikenard. I.

*Aralia spinosa* L. Hercules' club. VI.

*Hedera helix* L. English ivy. Marsh Hall.

*Panax quinquefolium* L. Ginseng. Found in I as late as 1914.

## Umbelliferae—Parsley Family.

**Cryptotaenia canadensis** (L.) DC. Honewort. I, II.**Daucus Carota** L. Wild carrot. General in the open.**Osmorhiza Claytoni** (Michx.) Clarke. Sweet cicely. I.**Sanicula canadensis** L. Short-styled snakeroot. I, II.**Sanicula trifoliata** Bicknell. Large fruited snakeroot. I.

## Cornaceae—Dogwood Family.

*Cornus alba*, var. *siberica*.**Cornus florida** L. Flowering dogwood. I, II, V.*Cornus Mas* L. Cornelian cherry. V.*Cornus stolonifera*, Michx. Red-osier dogwood. V.**Nyssa sylvatica** Marsh. Sour gum. I, II.

## Ericaceae—Heath Family.

**Monotropa uniflora** L. Indian pipe. I.

## Primulaceae—Primrose Family.

**Lysimachia quadrifolia** L. Whorled loosestrife. II.

## Oleaceae—Olive Family.

*Chionanthus virginica* L. Fringe tree. V.*Forsythia suspensa* Vahl. Goldenbell. East entrance.*Forsythia viridissima* Linde. Goldenbell. East entrance.**Fraxinus americana** L. White ash. I, II, III.**Fraxinus quadrangulata** Michx. Blue ash. I.*Syringa vulgaris* L. Common lilac. Near buildings.

## Apocynaceae—Dogbane Family.

**Vinca minor** L. Periwinkle. I and on open hillsides.

## Asclepiadaceae—Milkweed Family.

**Asclepias purpurascens** L. Purple milkweed. IV.**Asclepias syriaca** L. Common milkweed. III, IV, V.**Asclepias tuberosa** L. Butterfly weed. (Jones.)

## Hydrophyllaceae—Waterleaf Family.

**Hydrophyllum appendiculatum** Michx. Appendaged waterleaf. I.**Hydrophyllum macrophyllum** Nutt. Large-leaved waterleaf. I.

## Boraginaceae—Borage Family.

**Lithospermum arvense** L. Corn gromwell. III.

## Labiatae—Mint Family.

**Agastache nepetoides** (L.) Ktze. Giant hysop. I.**Agastache scrophulariaefolia** (Willd.) Ktze. Figwort hysop. I.**Hedeoma pulegioides** (L.) Pers. American pennyroyal. II, III.

**Lamium amplexicaule** L. Henbit dead-nettle. III.

**Lamium purpureum** L. Red deadnettle. II, III.

**Leonurus Cardiaca** L. Catnip. IV, VI.

**Prunella vulgaris** L. Self-heal. General.

Solanaceae—Nightshade Family.

**Physalis pubescens** (L.). Low hairy ground-cherry. IV.

**Physalis Virginia** Mill. Virginia ground-cherry. IV.

**Solanum Dulcamara** L. Bittersweet. I, V.

**Solanum nigrum** L. Black nightshade. IV.

Scrophulariaceae—Figwort Family.

**Linaria vulgaris** Hill. Butter and eggs. III, IV, V.

**Verbascum Thapsus** L. Mullein. III, IV, V.

**Veronica arvensis** L. Corn speedwell. General in the open.

**Veronica peregrina** L. Purslane-leaved veronica. General.

**Veronica serpyllifolia** L. Thyme-leaved veronica. General.

Orobanchaceae—Broom-rape Family.

**Epifagus virginiana** (L.) Bart. Beechdrops. I, II.

Bignoniaceae—Bignonia Family.

**Catalpa bignonioides** Walt. Catalpa. V, VI.

**Tecoma radicans** (L.) Juss. Trumpet creeper. IV, VI.

Phrymaceae—Lopseed Family.

**Phryma Leptostachya** L. Lopseed. I.

Plantaginaceae—Plantain Family.

**Plantago lanceolata** L. Ribwort; English plantain. General.

**Plantago major** L. Greater plantain. General.

**Plantago Rugellii** Dene. Rugel's Plantain. General.

Rubinaceae—Madder Family.

**Galium Aparine** L. Cleavers. General in shaded places.

**Galium circaezans** Michx. Wild licorice. II, III.

**Galium concinnum** T & G. Shining bedstraw. II.

**Galium triflorum** Michx. Fragrant bedstraw. I, II.

**Houstonia caerulea** L. Bluets; Innocence. III.

**Houstonia longifolia** Gaertn. Long-leaved houstonia. III.

Caprifoliaceae—Honeysuckle Family.

**Diervilla grandiflora** S & Z. Weigelia. Near buildings.

**Lonicera japonica** Thunb. Japanese honeysuckle. III, IV, V.

**Lonicera sempervirens** L. Coral honeysuckle. II.

**Lonicera tartarica** L. Tartarian honeysuckle. Entrances.

**Lonicera Xylostereum** L. European fly honeysuckle. V.

**Sambucus canadensis** L. American elder. II, IV, VI.

*Sambucus nigra* L. European elder. East plaza.

*Symphoricarpos orbiculatus* Moench. Coralberry. Entrances.

*Symphoricarpos racemosus* Michx. Snowberry. Entrances.

*Viburnum prunifolium* L. Black haw. II.

Valerianaceae—Valerian Family.

*Valerianella radiata* (L.) Dufr. Beaked corn salad. IV.

Dipsacaceae—Teasel Family.

*Dipsacus sylvestris* Huds. Teasel. III.

Campanulaceae—Blue bell Family.

*Specularia perfoliata* (L.) A. DC. Venus's Looking-glass.  
II, III.

Lobeliaceae—Lobelia Family.

*Lobelia inflata* L. Indian tobacco. III, IV.

*Lobelia spicata* Lam. Pale spiked lobelia. II.

Compositae—Composite Family.

*Achillea Millefolium* L. Yarrow. General in the open.

*Ambrosia artemisiifolia* L. Common ragweed. General.

*Ambrosia trifida* L. Tall ragweed, II, IV, V.

*Antennaria plantaginifolia* (L.) Richards. Plantain-leaved  
everlasting. III.

*Anthemis Cotula* L. May weed. IV.

*Arctium Lappa* L. Burdock. III, IV, V, VI.

*Aster cordifolius* L. Blue wood aster. Common.

*Aster ericoides* L. White heath aster. III, IV, V.

*Aster novae anglicae* L. New England aster. III.

*Bidens bipinnata* L. Spanish needles. II.

*Bidens frondosa* L. Beggar-ticks. General.

*Chrysanthemum Leucanthemum* L. White daisy. III.

*Cirsium lanceolatum* Hill. Common bull thistle. IV, V.

*Erigeron annuus* (L.) Pers. Sweet scabius. General in the  
open.

*Erigeron canadensis* L. Horseweed. General.

*Erigeron Philadelphicus* L. Philadelphia fleabane. General.

*Eupatorium urticaefolium* Reichard. White snakeroot. I.

*Gnaphalium polycephalum* Michx. Sweet everlasting. III,  
IV.

*Hieracium venosum* L. Rattlesnake weed, II.

*Lactuca canadensis* L. Wild lettuce. III, IV, V.

*Lactuca scariola* L. Prickly lettuce. III, IV, V.

*Prenanthes altissima* L. Tall white lettuce. I, II.

- Senecio aureus* L. Golden ragwort. II, III.  
*Solidago caesia* L. Wreath goldenrod. II, I.  
*Solidago juncea* Ait. Early goldenrod. III.  
*Solidago rugosa* Mill. Tall hairy goldenrod. III, IV.  
*Solidago serotina* Ait. Late goldenrod. III, IV.  
*Taraxacum officinale* Weber. Dandelion. General.  
*Vernonia altissima* Nutt. Ironweed. III, IV, V.

Summary:

Families 74.

Genera 210

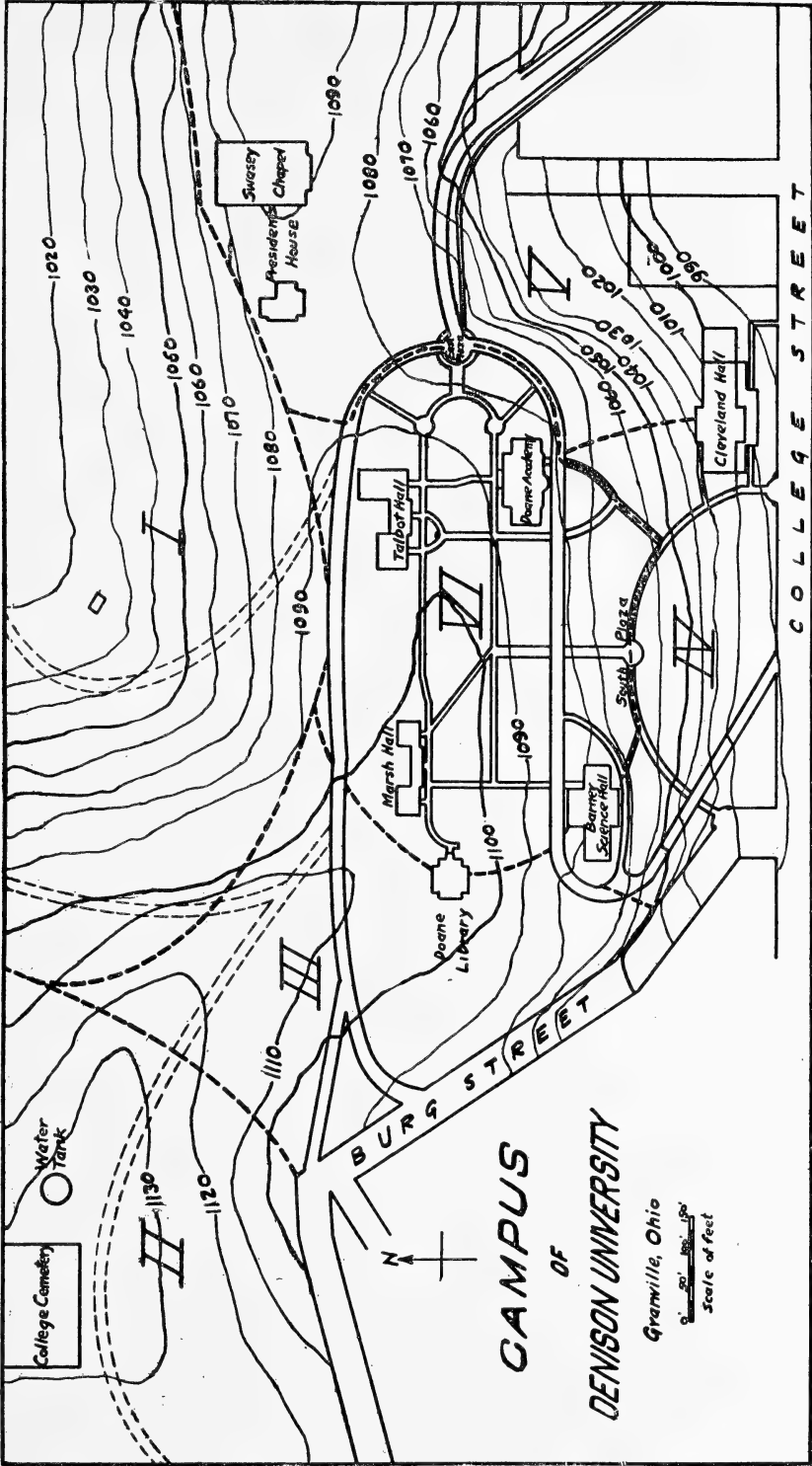
Species 321

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PLATE XVII

PLAN OF THE DENISON CAMPUS, SHOWING BOTANICAL AREAS



DWIGHT MUNSON MOORE

SURVEY OF CAMPUS OF DENISON UNIVERSITY

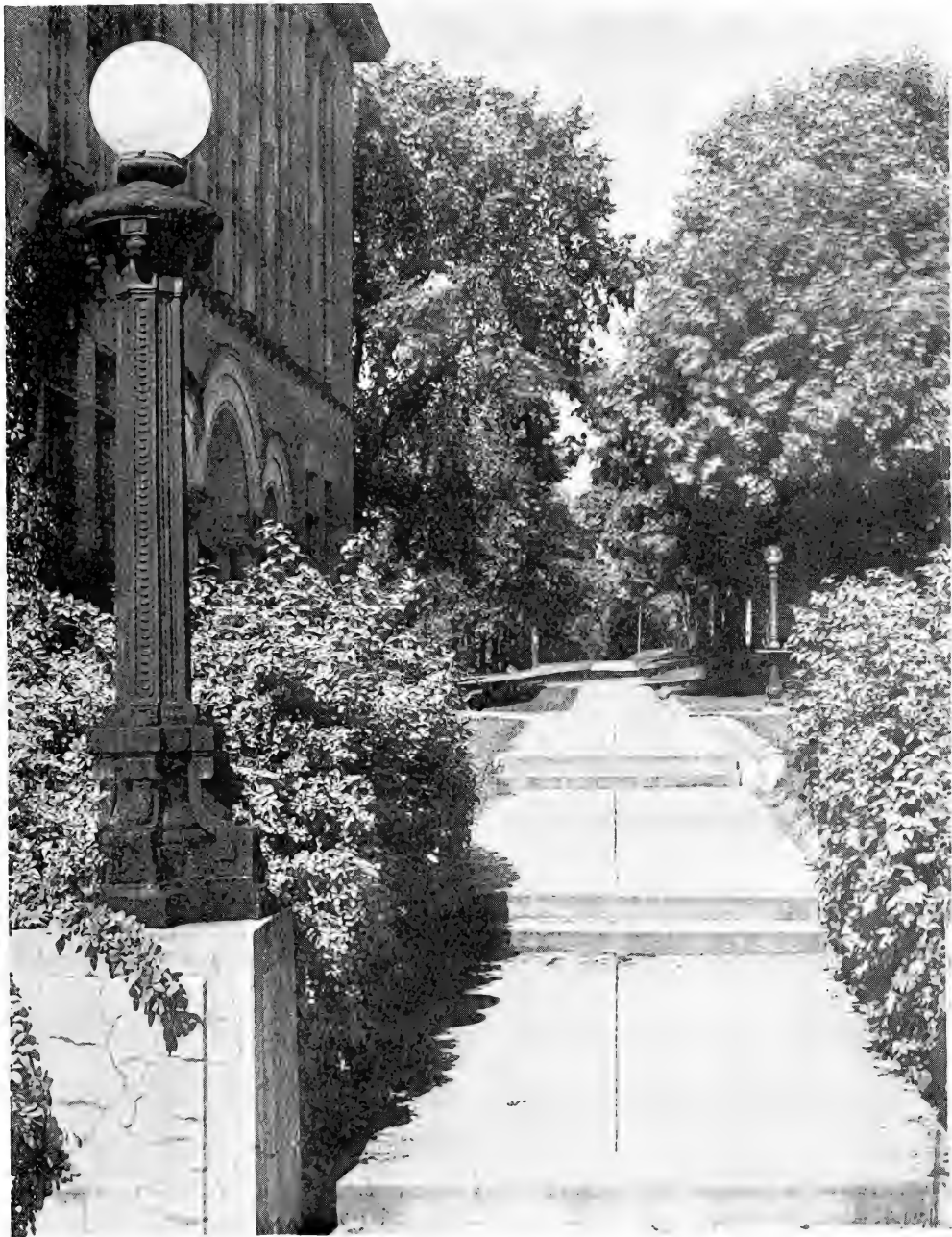
PLATE XVIII  
THE NORTH WOOD WITH HYDROPHYLLUM IN BLOOM



DWIGHT MUNSON MOORE      SURVEY OF CAMPUS OF DENISON UNIVERSITY

PLATE XIX

SHRUBBERY FLANKING THE WALK LEADING TO DOANE ACADEMY BUILDING



DWIGHT MUNSON MOORE

SURVEY OF CAMPUS OF DENISON UNIVERSITY



# THE UNDERGROUND MIGRATION OF OIL AND GAS

## THE PROBLEM

KIRTLEY F. MATHER

A necessary antecedent to the flow of oil or gas in commercial quantities into a drill hole is the concentration of a considerable amount of volatile hydrocarbons in a small space under conditions suitable to its ready release. There is much evidence for the belief that a very great percentage of the world's petroleum and natural gas has originated in the midst of finely divided sediments, the muds, oozes, clays and shales. It is also apparent that oil and gas wells, with few exceptions, derive their valued products from the midst of comparatively coarse-grained sands and sandstones or from the larger crevices of limestones and shales. Disseminated broadly through fine grained sediments, the hydrocarbons are valueless, except in so far as they may be removed by expensive treatment of the rocks. Concentrated in limited portions of sand or sandstone, these same compounds become one of the most valuable sources of energy and power available to man. The history of oil and gas particles from the time of their origin to the moment when they enter the casing of a well is not only interesting; a knowledge of it is essential to the application of geology to the oil and gas industry. The ability to determine the probable location of new fields in advance of drilling and the most favorable directions of extension of existing fields depend on a clear understanding of the laws governing the movement of hydrocarbons through the rocks and of the conditions which control the action of those laws.

This movement seems to comprise two phases, of differing nature and presumably therefore resulting from different causes. The first of these is the migration of oil and gas out of the fine-grained source rocks into the coarser-grained sediments. This results in the segregation of the available hydrocarbons in "sands."

It may be conveniently referred to as *transverse migration*, for the direction of movement is in general across the bedding planes of the rocks from one stratum to another. The second phase involves the concentration of mobile hydrocarbons in certain areas within the extent of the more porous beds. It must depend upon lateral movement of the oil and gas within a stratum or series of strata and may be called *parallel migration*, for the direction of movement is more or less parallel to the bedding planes. Both sorts of movement are involved in the origin of most accumulations of oil or gas of economic value.

Before drawing any conclusions as to the probable causes of these migrations in any particular case, it will be well to review all possible motive forces which may have been in any way responsible. Having assembled the data it will then be less difficult to select the more important agents and observe how they may have coöperated in the local accumulation of oil or gas.

#### THE MOTIVE FORCES

Strictly speaking, there are but two forces which in the last analysis may be the ultimate causes of underground migration of fluids or vapors; these are (a) gravitational force and (b) molecular force. Both of these forces, however, may operate in several ways. The direct action of either may affect oil and gas indirectly through a long chain of intermediate causes and results. Interaction and reaction between the two introduce a number of complications. A somewhat arbitrary grouping of the many proximate causes of migration must therefore be adopted.<sup>1</sup>

#### *Induration of sediments*

The genesis of oil and gas depends upon the entrapping of plant and animal tissue in the midst of accumulations of inorganic debris, which whether deposited by water or by wind, are at first loosely heaped together. The consolidation of fragmented

<sup>1</sup> For a classification of causes of oil migration different from that adopted here, see V. Zeigler, *The Movements of Oil and Gas Through Rocks*, Economic Geology, vol. 13, pp. 335-348, 1918.

material into "rocks," as that term is popularly used, is accompanied, at least in part, by the conversion of organic substances into bitumens. Both processes involve, or may involve, transition through a number of stages, none of which is separated from its neighbors by hard and fast subdivisions either in time or in space. Induration of sediments, and distillation of oil and gas progress simultaneously from the time of deposition on sea or lake floor or along the river flood plain. Each affects the other, sometimes favorably, sometimes adversely; but most important is the influence which induration of sediments has upon the location of the products of distillation. For purposes of analysis it is convenient to consider the processes of consolidation of fragmented material into "solid rock" under two heads: (1) compacting of sediments, (2) cementation of sediments. As a matter of fact, of course, the two processes may proceed more or less simultaneously.

#### *Compacting of sediments*

Much information of great importance to petroleum geologists concerning the consolidation of sedimentary material is wanting. Careful observations of the changes now going on beneath the shallow water of marginal seas are needed to make possible accurate interpretation of the results of similar changes which have taken place in the past. Such studies have been made by few, but will doubtless become a more important part of the education of the geologist of the future.

Sediments deposited by moving water must be at first loosely heaped on the basin floor; pore space is at a maximum; open spaces are filled with water. With increase of burden due to continual deposition of debris the loose accumulation must settle and be compressed into smaller dimensions. Shrinkage of volume beneath the weight of the overlying debris may greatly reduce the thickness of the accumulations. Shaw<sup>2</sup> reports, for example, that the shore of the Mississippi delta "is in places

<sup>2</sup> E. W. Shaw, The mud lumps at the mouths of the Mississippi; U. S. Geol. Survey, Prof. Paper, 85-B, pp. 11-27, 1913.

actually retreating, not so much by sea erosion as by settling, which in places predominates over upbuilding." This compacting of material must necessarily squeeze out fluids from the dwindling pores.

Sedimentary debris comprises three classes of material, clay particles, sand grains, and calcareous fragments, distinguished on the basis of composition and shape of individual particles rather than on the basis of size. Theoretically there should be an equal amount of compacting of earthy materials of the same composition and individual shape, under the same weight of overburden and with an equal time for adjustment, regardless of the dimensions of the the particles. Such classifications according to size as that of the Bureau of Soils, which applies the term sand to all earthy materials with dimensions between 0.05 and 1.0 mm., the term silt to those between 0.005 and 0.05 mm., and the term clay to all particles less than 0.005 mm. in diameter, are of value in this connection merely because they are also more or less perfect classifications according to chemical and mineral composition and therefore according to shape. Silt and clay particles are in a large degree tabular in shape, so they may fit together, like bricks in a wall, with small and few voids between them. Resistance to crushing of individual flakes is comparatively slight, so that flakes which do not assume approximately parallel orientation are broken and the fragments pushed into the proper plane. Sand grains, on the contrary, are roughly equidimensional or spheroidal in shape, so that they must fit together, like field stones in rubble-work, with large interstices between them. Crushing strength of individual grains is proportionally very much greater. Consequently, in any bedded deposit of interstratified clay and sand, the compacting of the clay strata is many times as great as that of the sand layers, and because reduction of pore space is proportional to amount of compacting, fluids will be squeezed from the midst of the clay much more completely than from the voids in the sandy beds. Calcareous debris would probably be intermediate between clay and sand in its reaction to compacting stresses.

Beyond doubt, the first stages of formation of organic material into bitumens are contemporaneous with burial in the silt or ooze of the basin floor. Synthesis of oil and gas is at a maximum in the midst of muds and silts, and is at a minimum in sandy beds. Compacting of the former drives out the fluids and gases to a great extent. Some of these escape upward into the water or air above the accumulating sediments, but much of them must first pass through the pores and openings of interbedded sandy layers. Here differential surface tension and viscosity tend to hold the newly formed petroleum, and may effectively segregate it in the coarser beds. Thus at the very start of the process of oil formation this transfer of oil from its place of origin in the muds to its place of storage in the sands begins.

Continued accumulation of debris in the lodgment basin means deeper burial and increased compactness of the successive strata. More and more of the fluid content of the muds and shales is forced out, and more impenetrable become the overlying strata which prevent the escape of the increasing volume of oil or gas from the sandy reservoirs into which it has been driven. Eventually the muds, silts, and clays become shale and the sands become sandstone. Loose debris is now "solid rock" and compacting of sediments becomes henceforth a quantitatively minor matter. Shale and sandstone alike acquire sufficient rigidity and strength to support the weight of a considerable thickness of overburden.

Nevertheless, compacting does not entirely cease when the sediments are consolidated into "rocks." Somewhere below the surface is a zone below which voids cannot exist within the rocks; deformation there takes place by rock flowage rather than by rock fracture. The thickness of overburden necessary to produce sufficient pressure to close all openings is generally believed to be about eleven miles, and the notion is prevalent that a "zone of flow" exists at some such depth as that. It should be noted, however, that the eleven-mile column is necessary to deform the *strongest* rocks, while the weaker rocks will "flow" under much less pressure. The "zone of flow" is not a true "zone," but a condition in which different rocks are found

at vastly different depths below the surface. Indeed it would in most cases be extremely difficult if not impossible to draw a line between compacting of sediments and rock flow; the one grades imperceptibly into the other. The "zone of flow" is almost at the surface for certain materials, among which the most conspicuous are the mud rocks which are pre-eminently the birthplace of petroleum. The Mississippi Delta, according to Shaw,<sup>3</sup> seems to be affected by "a bodily flowage toward the sea." In places the Delta front is bulging outward and upward as the materials of which it is composed flow laterally after having been compacted by the weight of the shallow overburden.

Such flowage of the rocks may further the process of transfer of petroleum from shales to sandstone or to limestone, but is probably much less important than the universal compacting which necessarily must result from the accumulation of any considerable amount of sediment in any lodgment basin. The movement, both of solids and of fluids, which must accompany rock flow may greatly expedite the segregation of oil and gas by other processes to which reference is made in the succeeding paragraphs. In general, simple compacting precedes rock flow and decreases in importance as the later process increases in amount, but no sharp distinction may be drawn either between the processes or their results.

#### *Cementation of sediments*

Consolidation of sediments is not solely nor indeed principally a matter of compacting; especially are the constituents of sandy strata bound together by interstitial cement. Cementation may begin immediately after the rocks are subjected to the action of ground water. It is through cementation that sands become sandstone, and sandstones become quartzite. Obviously, the greater the amount of precipitated cements the less the effective pore space of the rock. If cementation commences along a definite plane or at a point and proceeds regularly

<sup>3</sup> Loc. cit., pp. 17, 18.

outward, it will necessarily exclude ground water, oil, or gas, from the pores which it closes and may drive fluids and gases into other portions of the reservoir. The distinction between the sands reported by the driller as tight (and dry) and those stated to be loose (and water, gas, or oil-bearing) is probably in most cases a result of differential cementation.

At present, however, it is impossible to say whether a tight sand is devoid of oil because the cementation of the sand drives out its fluid content or because the presence of cement filling the pores prevented the immigration of valued hydrocarbons; probably the latter is more often the case. In general, it should be observed that the presence of oil in a rock pore will itself hinder if not entirely prevent the filling of that pore by cement carried in aqueous solutions. Between the encroaching cement and the retreating oil there must always be a buffer of water. It is doubtful whether progressive cementation of sediments has even been an important cause of the migration of oil or gas.

### *Capillary action*

Molecular forces are by no means completely understood. The exact nature of both inter-molecular and intra-molecular attractions and repulsions are more or less of a mystery. The best that can be done in the present state of knowledge is to give names to the more obvious phenomena resulting from these forces, and to postpone the enquiry as to their fundamental causes until the physicist and the chemist have completed their research concerning them.

Of the phenomena attributable to molecular action, the two most important in this connection are capillarity and surface tension. Surface tension is the property "which exists in the surface film of all liquids and tends to bring the contained volume into a form having the least superficial area." It is this property which causes small quantities of oil, water, mercury, or other fluids to form into spherical "drops" when scattered over the surface of a solid or sprayed into the air. It apparently results from cohesion, the attraction existing between closely adjacent molecules of the same substance, a force which is "quite

insensible between two portions of matter separated by any distance which we can directly measure." Consequently within a liquid body each molecule which is more than about the twenty-thousandth part of a millimeter distant from the surface is affected equally on all sides by cohesion with other molecules which surround it. But the molecules in the surface film are on the whole attracted inward, and tension results. The amount of this tension depends upon the curvature of the surface, the composition and temperature of the liquid, and the nature of the surrounding medium or media.

Capillarity<sup>4</sup> is "the action by which the surface of a liquid, where it is in contact with a solid is elevated or depressed." Because of it the surface of the water in a glass is not plane but is curved upward around the margins, and for the same reason the top of the mercury column in a thermometer is convex upward instead of flat. But the phenomenon is best observed when liquids enter tubes or spaces of small diameter or width, for then it may cause the liquid to move in a direction quite contrary to that in which it would be impelled by gravity. The absorption of a drop of ink by blotting paper in which the tiny air spaces between the paper fibers draw the fluid upward, or the continual supply of oil through the wick of the kerosene lamp, which keeps the flame steadily burning several inches above the oil reservoir, are familiar illustrations. Capillarity is in part a result of surface tension but depends also upon the forces of adhesion, forces which act between closely adjacent molecules of unlike substance, those of the liquid and of the containing solid.

Capillary action may best be considered as operating in tubes of small diameter or in fissures of minute width. Openings into which a liquid is drawn with a force greater than that exerted by gravity may be referred to as capillary openings. In such openings the mean height to which the fluid rises varies inversely as the radius of the tube or the width of the fissure. The capil-

<sup>4</sup> For a clear exposition of capillarity see J. C. Maxwell's article "Capillary Action," revised by Lord Raleigh, in *Encyclopedia Britannica*, eleventh edition, 1910.

lary pull also varies with the surface tension of the fluid and is at once affected by any change in surface tension. A water-air surface at ordinary temperatures has a tension of 70 to 75 dynes per square centimeter, and so far as water is concerned, all tubes of diameter less than 0.508 mm., and all smooth fissures less than 0.254 mm. wide are capillary. According to Washburne,<sup>5</sup> "a salty water, such as that commonly found in oil fields, having a density of 1.14 at 20°C., would have a surface tension of about 79 dynes per centimeter," while Pennsylvania crude oil with a specific gravity of 0.852 displayed a surface tension of only 24.1 dynes per centimeter at 20°C. The same author is responsible also for the statement "that all crude oils have low surface tension, probably in the neighborhood of 25 dynes, except only the oils that have lost all of their light constituents, which are of no consequence in problems of deep migration." Because of their low surface tension, only those tubes with a diameter of less than about 0.25 mm., and fissures not over 0.13 mm. wide are capillary openings with respect to the average crude oil.

Surface tension decreases with increase in temperature and becomes zero at the critical temperature of each substance; capillary action is therefore limited to the outer shell of the earth and cannot be operative at great depths where temperatures are high. "The effect of pressure on surface tension (and therefore upon capillary action) is unknown, but is presumably small."<sup>6</sup>

Finally in summing up these physical factors concerning capillarity, it should be noted that although capillary action may draw fluids into small passageways within the rocks it cannot of itself induce continued flow through these passageways. Since it is an expression of surface tension, capillarity is operative "only when there is a free liquid surface within the capillary." Once the capillary opening is filled with liquid, capillary action ceases, unless perchance another liquid of different surface tension approaches an opening of the tube.

<sup>5</sup> C. W. Washburne, The capillary concentration of gas and oil, *Trans. Am. Inst. Min. Eng.*, vol. 50, pp. 829-858, 1915.

<sup>6</sup> John Johnson and L. H. Adams, Observations on the Daubree experiment and capillarity in relation to certain geological speculation, *Journ. Geol.*, vol. 22, pp. 1-15, 1914.

*Capillary action on crude oil in dry materials; experimental data*

*Dissemination through fuller's earth.* Experiments conducted by David T. Day<sup>7</sup> indicate that in spite of its relatively low surface tension crude oil disseminates rapidly in dry, finely divided material such as fuller's earth. Not only does oil rise directly against gravity to a height of 5 or 6 feet in a tube packed with fuller's earth, "but if the tube be sealed at the upper end the oil will still rise in the tube, driving out the air in the pores of the earth and compressing it in the upper part of the tube with a pressure sufficient to blow out the clay if the top of the tube be suddenly broken off and the air thus released."

No experimental data are available as to the exact size of the capillary spaces through which the oil is thus forced to migrate, but somewhat similar movement is known to take place through finely divided quartz sand and amorphous silica.<sup>8</sup> More than likely the upper limit of pore sizes conforms to that suggested above as the theoretical dimensions of capillary openings for crude oil.

*Effect of dissemination upon composition of crude oil.* "When a glass tube is packed tightly with dry fuller's earth, and one end is allowed to stand for one or two days in crude petroleum the oil diffusing up through the clay fractionates to a considerable extent. Thus, when the upper fifth portion of the clay is dropped into water, a lighter gravity oil is driven out by the water. This first fraction is entirely colorless. The lower fractions are heavier and more and more highly colored. The bottom section may be almost solid, and is darker in color than the original oil. A fractionation by diffusion has been effected, which is similar to fractionation by distillation, but is not so complete."<sup>9</sup> Richardson<sup>10</sup> made similar tests with crude oil from Texas and found that sulphur compounds could be separated from that oil by their failure to migrate into fuller's earth.

<sup>7</sup> David T. Day, The conditions of accumulation of petroleum in the earth, Am. Inst. Min. Eng., Trans., vol. 41, pp. 219-224, 1911.

<sup>8</sup> David T. Day, Experiments on the diffusion of crude petroleum through fuller's earth, Science, N. S., vol. 17, pp. 1007-1008, 1903.

<sup>9</sup> Day, loc. cit., p. 222.

<sup>10</sup> Clifford Richardson, Journ. Soc. Chem. Ind., vol. 21, pp. 316-17, 1902.

Apparently "the size of the capillaries is of great consequence in these diffusion phenomena. Finely divided material, such as amorphous silica, has no observable fractionating-power on oils that are readily fractionated by dry clays." Quartz sands likewise exhibit practically no selective action, but dried shale of Devonian age proved to exert an action similar to that of fuller's earth.

As shown by Engler and others, there is no chemical change in this process; fractionation by capillary dissemination is merely a mechanical separation of slowly diffusing liquids from those which pass more rapidly into the capillary spaces.

*Application to the conditions existing in the earth*

Except in arid regions, the pores of all sedimentary rocks near the surface of the earth are more or less completely filled with water; but the deeper levels which have been penetrated by the drill in the Appalachian oil fields and elsewhere are apparently dry. Oil field waters will be discussed in a subsequent section of this paper; it is here only necessary to call attention to the fact that the amount of water found in the sedimentary rocks of most oil fields decreases with depth. In the Appalachian region "fresh water is found in appreciable amounts in one or more beds as a rule to a maximum depth of 200 to 800 feet. Brackish or salt water occurs below the fresh water at depths ranging from 400 to about 3000 feet. In a few wells out of the thousands drilled, salt water was found at greater depths than 3000 feet, but in all cases the amount and head of this water was very small, regardless of the porosity of the containing bed. In many wells open porous sandstones from 1000 to 3000 feet from the surface show no water. Many of these were found to take up, with surprising rapidity, water poured into the well in the process of drilling."<sup>11</sup> This is by no means equivalent to stating that shales three or four thousand feet below the surface of the earth are known to be dry, but it

<sup>11</sup> M. J. Munn, *The Anticlinal and hydraulic theories of oil and gas accumulations*, Econ. Geol., vol. 4, pp. 509-529, 1909.

strongly suggests the possibility that at some such depth certain of the finer grained sediments may be nearly or quite devoid of moisture. If so, oil entering or present in the small pores of these shales would be broadly disseminated throughout the rock by capillary action. This is just the opposite movement to that requisite for the accumulation of oil in economic quantities, but such migration may have been preliminary to certain processes of accumulation.

The influence of such capillary migration upon the composition of oils subjected to it is probably the only effect of quantitative importance to the oil industry. As suggested by Day, it is possible to explain the difference in the nature of the oil of different fields by the hypothesis "that dark colored oil (possibly containing sulphur and asphalt) entered shales varying in fractionating-power, due to varying porosity or moisture," and was there fractionated into oils of various colors and compositions. It is even possible, although in the opinion of the present writer scarcely probable, that the oils from the Carboniferous rocks of Pennsylvania and vicinity are "the same as the Ordovician limestone oils of Ohio, with the sulphur removed by diffusion." Furthermore, the long series of quantitative tests made by Gilpin and Cram<sup>12</sup> indicate that the paraffin hydrocarbons diffused farther than the unsaturated or asphaltic hydrocarbons which were consequently left behind in migration due to capillary attraction. The strong contrast between the paraffin oils of Pennsylvania and the asphaltic oils of California may be an illustration of the effect of capillary dispersal resulting in fractionation or filtration in the one case and the absence of this action in the other.

*Differential capillarity of oil and water; experimental data*

In the experiments conducted by Day, Gilpin and Cram, above referred to, in which crude oil was drawn upward by capillary action into tubes packed with dry fuller's earth, the

<sup>12</sup> J. E. Gilpin and M. P. Cram, The fractionation of crude petroleum by capillary diffusion, U. S. Geol. Survey, Bull. 365, 1908.

oil was later displaced from the earth by water. Fractions of the earth removed from the tube and dropped into water, rapidly gave up their content of oil, and the pores formerly occupied by oil became filled with water. Several experiments which approximate more closely the conditions existing within the earth have been described by McCoy,<sup>13</sup> Mills,<sup>14</sup> and Cook.<sup>15</sup> In one of McCoy's experiments, an open glass cylinder was placed in a pan of wet sand, so that the sand filled the lower one-third of the cylinder. The water had free access from the sand in the pan to the sand in the cylinder. A layer of oil-saturated mud, made by adding Oklahoma crude oil (38°Beaume) to a mixture of dried clays, the particles of which measured from 0.005 to 0.001 mm., was placed in the cylinder upon the wet sand; this mud occupied about one-third of the cylinder and was above the level of the water in the pan. The cylinder was then filled with *dry* sand, and the top sealed with a tube attachment to a closed barometer. Within twenty-four hours, the water migrated upward about 1 cm. into the mud, and the oil moved about the same amount into the dry sand; some of the oil also migrated down into the wet sand and collected in the larger openings; the mercury rose in the closed barometer to a height of about 2.5 cm. above that corresponding to the atmospheric pressure. As thus described the experiment is essentially a modification of the Daubree experiment of 1861, in which water passed through sandstone against pressure,<sup>16</sup> or of the "atmometer"<sup>17</sup> which gives similar results. The most significant, obvious

<sup>13</sup> A. W. McCoy, Some effects of capillarity on oil accumulation, Jour. Geol., vol. 24, pp. 798-805, 1916; reprinted, Bull. Southwestern Assoc. Petrol. Geolog., vol. 1, pp. 140-47, 1917.

<sup>14</sup> R. V. A. Mills, Experimental Studies of subsurface relationships in oil and gas fields, Econ. Geol., vol. 15, pp. 398-421, 1920.

<sup>15</sup> C. W. Cook, Study of capillary relationships of oil and water, Econ. Geol., vol. 18, pp. 167-72, 1923.

<sup>16</sup> Daubree, Etudes Synthetiques de Geologic Experimentale, Paris, 1879, pp. 238.

<sup>17</sup> J. Johnston and L. H. Adams, Observations on the Daubree experiment and capillarity in relation to certain geological speculation, Jour. Geol., vol. 22, pp. 1-15, 1914.

result in the present connection is the downward migration of oil from the extremely small pores between the mud particles to the larger interstices between the sand grains, which had previously been filled with water.

In McCoy's second experiment, a layer of wet sand was arranged in the form of an anticline between two layers of oil saturated mud. The sand grains near the crown of the artificial anticline were small, all passing a 40 mesh sieve, while those on the limbs were coarser, none passing a 10 mesh sieve. The top of the rectangular glass box containing the three layers was sealed with paraffin and water allowed to enter through openings at the lowest horizon of the sand, but was kept at a level below the top of the curve in the sand. Water entered the mud both above and below the sand layer, and replaced about an inch of the oil in the mud. The displaced oil moved into the interstices between the coarser grains of sand and within 24 hours there was an "oil pool" in both limbs of the anticline on either side of its water-filled crest. These results could not have been effected by simple capillary pressure such as that operative in the Dabbie experiment because the spaces between sand or mud particles were occupied with either oil or water and the paraffin seal over the top of the box prevented evaporation. There were, however, certain forces at work which drove oil out of small openings into large ones and at the same time drew water from the larger to the smaller pores, regardless of the direction involved in the transfer or of the tendency of oil to float on top of water.

In many of Mills' experiments, coarser sands were used, and water circulation, sometimes under considerable head, was involved. Few of them afforded much opportunity for capillary action to display itself. Nevertheless, capillary adjustments seem to have occurred between oil and water in saturated strata. These, states Mills, are restricted within short lateral ranges, amounting to only a few centimeters in his experiments. His conclusion was that the principal rôle of capillarity, in saturated strata, is to retard rather than to promote fluid movements.

*Theoretical considerations*

As stated above, the surface tension of crude oil is between one-third and one-half that of water. Capillary action must therefore exert a much stronger pull upon water than upon oil. According to Washburne,<sup>18</sup>

the amount of the capillary pull varies inversely as the diameter of a pore, hence the constant tendency of capillarity is to draw water, rather than oil, into the finest of openings, displacing any gas or oil in the latter. Gas itself is not drawn into capillaries by the action of surface tension, and it can leave the fine pores without any capillary resistance. It is therefore the most quickly and most completely gathered in the largest spaces available. Moreover, capillarity resists any movement of water from fine toward large pores more than it resists the movement of oil or gas in that direction. In short, water enters fine capillaries about three times as readily as oil, and it encounters about three times as much capillary resistance in leaving them.

The final result of this action must be the concentration of nearly all the gas and oil in the openings having least capillary power, namely, in fissures if present, and in the larger rock pores. This appears to be the general rule in oil fields, where the pores of the coarser-grained rocks contain practically all of the oil, while the pores of the adjacent fine-grained rocks contain practically no oil.

Here, too, is a possible explanation of the phenomena displayed in the experiments described above. Differential capillary attraction may be competent to induce the migration of water from larger pores into adjacent ones originally filled with oil and to force the oil out of these spaces into those originally occupied by water.

There is, however, a possible fallacy here.<sup>19</sup> In comparing the surface tension of oil and of water, the comparison was between the tension on an oil-air surface and that on a water-air surface. In the experiments with saturated sediments, and presumably under most conditions obtaining within the earth,

<sup>18</sup> C. W. Washburne, The capillary concentration of gas and oil, Trans. Am. Inst. Min. Eng., vol. 50, pp. 823-858, 1915.

<sup>19</sup> Cf. Johnson, R. H., The Time Factor in the Accumulation of Oil and Gas, Bull. Am. Assoc. Petrol. Geologists, vol. 5, pp. 475-481, 1921.

it is the molecular forces operating on an oil-water surface which are significant. Here quantitative data are not available; Cook's tentative conclusion, that the minimum size of opening, which will allow the interchange of oil and water to occur, is considerably larger than the minimum which will permit the capillary movement of either oil or water alone, would suggest that the simple numerical ratio cited by Washburne does not directly apply.<sup>20</sup> Nevertheless, it is evidently a fact that under certain conditions this interchange of oil and water does take place exactly as though the movements were induced by capillary action. Probably, as Cook points out, the effects of differential adhesion of oil and water, especially the far superior adhesion of water for rock, are quantitatively more important than those resulting from differential cohesion of these same liquids as expressed by their surface tension. The phenomena of adhesion undoubtedly play an important part in capillary action and may be largely responsible for the interchanges of oil and water, which have been observed.

The direction of the movement resulting from such interchange is entirely independent of gravity; impelled by differential capillary forces, oil or gas may migrate upward or downward or laterally with equal facility. Migration would be from smaller to larger openings in the rocks, and presumably cannot reverse itself so long as water is present. Probably, neither oil nor gas can, under ordinary conditions, move into a stratum or portion of a stratum of rock which contains no openings of greater than capillary dimensions (for water) and is thoroughly saturated with water.

*Application to the conditions existing in the earth*

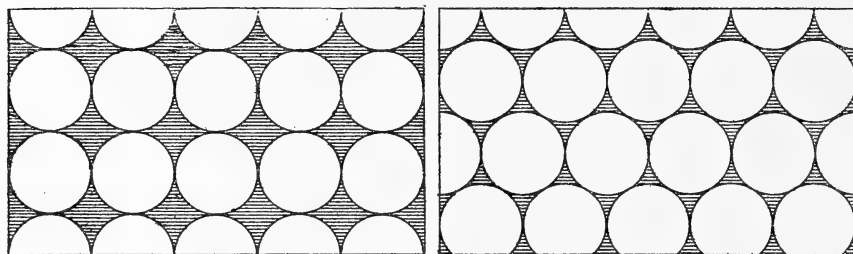
These considerations make evident at once the imperative necessity of data concerning the pore spaces existing in sedimentary rocks at different stages in their history. Not only should the total amount of pore space be known, but, of probably

<sup>20</sup> See also Skirvin, O. W., Experimental Study of the Invasion of Oil into a Water-Wet Sand, Econ. Geol., vol. 17, pp. 461-469, 1922.

much greater importance, the size of the spaces in different kinds of rocks under different conditions should be determined.

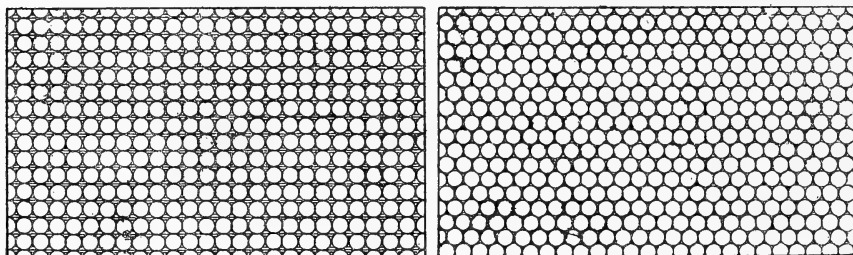
*Porosity of sedimentary rocks.* The total volume of pore space in a rock does not depend upon the size of the rock particles but upon their shape, assortment, arrangement, and degree of cementation. In figure 1, for example, the total amount of pore space in A and C, or B and D, is the same, but there is a progressive decrease in the diameter of the individual pores from the ideal case shown in A to that in D. Variations in the dimensions of interstices in elastic rocks must in general be roughly proportional to the size of rock grains, other things being equal. It is not, however, the average size of grain which is the most important consideration, but the proportion of extremely fine particles which if present in sufficient amount would "sift" into the larger spaces between the coarser grains and leave openings with dimensions approximating one-sixth to one-half the diameter of these smallest components of the rock. An argillaceous sand might, therefore, have pore spaces the dimensions of which would approximate those of the interstices between the particles of clay in shale. The more perfect the assortment by size and the "cleaner" the sand, the larger will be the voids in the rock. But this neglects the effect of cementation which as evidenced in diagrams E, F, and G, of figure 1, greatly influences the size of pore as well as the total amount of porosity. With these variables, it is readily apparent that abrupt changes in pore dimensions as well as in volume of openings may be expected in any sedimentary series when traced laterally or traversed vertically.

Data are not available for more than a broad approximation covering the relative sizes of pores in shales and sandstones. It is probable however, that interstitial spaces in most shales, are less than 0.01 mm. in diameter, and in the finer clay shales, especially if considerably compressed, openings would average less than a micron (the thousandth part of a millimeter) in cross-section. Sandstones display greater variation in size of pores because of the limitless variations in amount of cement and in abundance of fine constituents. The sands used by



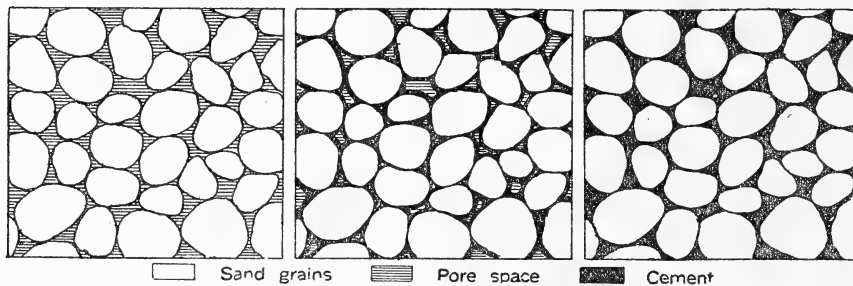
A. Hypothetical rock with large spherical grains, maximum pore space.

B. Hypothetical rock with large spherical grains, minimum pore space.



C. Hypothetical rock with small spherical grains, maximum pore space.

D. Hypothetical rock with small spherical grains, minimum pore space.



E. Irregular grains without cement, showing maximum pore space.

F. Irregular grains with interspaces partly filled with cement.

G. Irregular grains with interspaces completely filled with cement, no pore space.

FIG. 1. PORE SPACE OF ROCKS

(Reproduced with permission from Geological Survey of Kansas, Bull. 3, pl. III, 1917)

King<sup>21</sup> in measuring the observed pore space in soil and rock are reported to have had an "approximate effective diameter" which varied from less than 0.1 mm. to more than 2.5 mm., with the greater number of samples approximating 0.2 and 0.3 mm. It is entirely out of the question to apply any rigid mathematical formula stating the relation between pore size and sand grain diameter. Irregularity of outline of the sand particles is so great in the average sandstone that the common assumption of an accumulation of spheres is scarcely an approximation to the truth. To assume that the grains are spheres gives neither the maximum nor minimum total porosity or size of pore. "For simple sands with angular grains the pore space is much larger than it is for the rounded sands of the same sizes of grains, and in the case of crushed glass, whose grains are more angular than those of the crushed limestone, which have a tendency to be cuboidal in form, the pore space is the largest of all."<sup>22</sup> If this is true for total pore space, it must necessarily follow that the size of individual pores is greater in sandstones composed of angular grains than in those composed of rounded grains of similar sizes. The dimensions of occasional pores may equal the diameter of the sand grains if the latter are angular. The width of the open spaces between grains of ordinary sandstones may therefore vary from less than a micron to more than a millimeter. Probably the average pores of a poorly cemented sandstone would be between 0.1 and 0.5 mm. in width.

*Transverse migration of oil and gas.* In any series of alternating shales and sandstones, containing sufficient water to fill the openings in the shales, oil and gas will therefore tend to move from the shales and segregate in the sandstone strata. This transverse movement of the hydrocarbons will not be complete. In the first place there will almost certainly be porous lenses in the shale beds, entirely surrounded by compact shale with finer openings. Oil once driven into these lenses cannot afterward return into the finer peripheral pores as long as they are filled

<sup>21</sup> F. H. King, Principles and conditions of the movements of ground water, U. S. Geol. Surv., 19th Ann. Rept., Pt. 2, pp. 59-294, 1899.

<sup>22</sup> King, loc. cit., p. 215.

with water; hence it cannot traverse a zone of wet shale, all the openings in which are finer than those in which the oil occurs even though a coarsely porous sandstone may be only a few inches distant. In the second place, a considerable fraction of the oil will be retained in the argillaceous rocks by absorption and adhesion, as indicated by the experiments of Gilpin and Cram<sup>23</sup> who state "when oil is mixed with fuller's earth and then displaced with water, about one-third of the oil remains in the earth." These capillary forces would probably be most effective in their task of draining the shales of oil and gas and segregating these substances in the sandy beds if the latter were present at frequent intervals in the midst of a thick shale series. Recurrence of sandstones is more favorable than the same amount of sand deposited in a single massive bed, but in any event it is apparent that nothing could be more effective as a seal to stop transverse migration of either oil or gas than a water soaked bed of shale capping the sands. Once driven into the sandy horizons the hydrocarbons are there imprisoned, unless super-capillary fissures traverse the shales.

A consideration of the variability of dimensions of pore spaces in any sedimentary series makes it evident that migration of oil and gas due to capillary forces cannot in most cases extend over great distances. The very forces which impel segregation in the coarser pores make it impossible for hydrocarbons to traverse the average sedimentary series from bottom to top unless there are open fissures to serve as channels. Nor can the oil be gathered by lateral movement within a bed from distant points to a center of accumulation. Capillarity may only be appealed to as the force responsible for the transfer of oil or gas from one bed of fine-grained rock to a closely adjacent bed of coarser or more open texture, but in probably every oil field other forces have coöperated to concentrate the fluid in small enough compass to make an accumulation of commercial value.

*Localization of capillary segregation near surface of earth.* Surface tension decreases with increase in temperature until

<sup>23</sup> J. E. Gilpin and M. P. Cram, The fractionation of crude petroleum by capillary diffusion. U. S. Geol. Surv., Bull. 365, p. 33, 1908.

at the critical temperature of the substance it vanishes. The tables prepared by Johnston and Adams<sup>24</sup> indicate that with a temperature gradient of 1°C. per 100 feet the total pressure upon a water surface inside pores having diameters of 0.01 microns at a depth of approximately 1 mile would be no greater than the pressure outside the pores due to overlying rock. "Moreover, the surface tensions of all but the lightest hydrocarbons decrease much less rapidly than that of water for each increment of temperature, so that the surface tension of water does not have such great excess over that of oil" at depths of a mile or two as it does in the zone of lower temperature close to the earth's surface. It is therefore probable that capillary segregation of oil and gas must all be effected within two or three miles of the ground surface. At greater depths oil must remain disseminated throughout the shales, if that were its original distribution, unless it had migrated into the sandy strata during the time when the beds concerned were closer to the surface.

#### *Gravitation*

Migration of oil is caused directly and simply by the force of gravity only under certain restricted conditions. To permit oil to flow "down hill" in obedience to the attraction of gravity, the oil drops must be in openings not filled with water, and of super-capillary (for crude oil) dimensions. If the openings are tubular, their diameter must be greater than 0.25 mm.; if fissures, they must be more than 0.12 mm. wide. Pores and crevices of greater size than this are probably present in many sedimentary rocks near the surface of the earth, but more commonly they are filled with water. If water is absent from such a coarsely porous rock into which oil has moved, the oil will flow to the lowest portion of the porous stratum and may there collect in commercial quantities. Or if only sufficient water is present partly to fill the open spaces in the bed, the downward passage of the oil will be arrested when it reaches the water-bearing portion of the porous rock.

<sup>24</sup> J. Johnston and L. H. Adams, Observations on the Daubree experiment and capillarity in relation to certain geological speculations. Jour. Geol., vol. 22, p. 13. 1914.

*Differences in specific gravity*

Although the direct influence of gravitation is probably not generally important in causing underground migration of oil or gas, its indirect effect through differences in specific gravity of fluids and gases is unquestionably of prime importance. Most crude oils are quite appreciably lighter than water, especially the heavy salt water which is commonly associated with oil. The excess in specific gravity of water varies from more than 35 per cent, in the case of a very light oil compared with a heavy brine, to less than 5 per cent, if heavy oils be compared with dilute brines. An ordinary crude oil, with a specific gravity of 32° or 33°Baumé, is about 20 per cent lighter than the ordinary salt water with which it is commonly associated. If, then, petroleum and water are associated together in openings of super-capillary size, the difference in specific gravity will result in a tendency for the oil to rise until its upward progress is barred by a rock mass in which the openings are all of capillary size and are filled with water, or until it reaches the surface of the water body which displaces it.

*Gravitational sorting of oil and water.* The tendency of water thus to drive oil upward in coarsely porous strata is unquestioned; the actual movement of oil due solely to differences in specific gravity is by no means certain. If drops of oil are squeezed from a fountain pen filler against the bottom and sides of a basin filled with water, it may be observed that "most of the drops cling persistently to the vessel and do not rise through the water." The slight difference in weight between the small drop of oil and an equal volume of water is not sufficient in itself to overcome adhesion between the liquid and the adjacent solid, although the area of solid contact is very much less than that which would be operative if the same drop of oil were spread out in the pores of the ordinary sandstone. The drops of oil in the basin of water may be dislodged by stirring the water or by tapping the vessel; or if separate drops are so closely adjacent that cohesion and surface tension unite them into a single large drop, its size may be sufficient to induce

enough lifting force of water displacement to overcome adhesion and inertia, and to float it freely upward. All three of these phenomena are active in the interstices of the rocks. Circulation of ground water may simulate the first; crustal movement, tidal kneading, and earthquake vibrations are the second; and molecular forces are probably identical beneath the surface of the earth to those in the laboratory. But, in the petroliferous rocks, if an oil drop starts to obey the impulse of gravitative displacement, its upward progress is hindered by the friction of the rock surfaces past which it must move. The retarding effect of friction cannot be quantitatively determined from the data now available; it is entirely possible that it may in most instances prevent effective gravitative assortment of oil and water, although this is by no means certain.

*Gravitational sorting of gas and water.* The displacement of gas bubbles in water is quite another matter. Gas rises through water-saturated sandstone several hundred times as readily as oil. Differences in specific gravity are probably quite competent to concentrate gas above the water body in a porous rock mass. It is probable that soon after the formation of a bubble of gas, as a result of chemical action, change of temperature, or increase in pressure, the bubble would rise through the water in any supercapillary fissure or pore until ascension was stopped by a barrier of water-filled spaces, none of which were of more than capillary dimensions.

*Effect of gas migration in transporting oil.* But if while being forced upward the bubble of gas touches a droplet of oil clinging to the wall of fissure or pore, it will be surrounded by a thin film of oil, for oil has an extraordinary capacity of spreading along any surface between water and gas.<sup>25</sup> Each bubble of gas rising from its place of origin or later moving upward through rock cavities may carry with it a pellicle of oil and thus accomplish gravitational sorting of oil as well as of gas. When the gas bubbles with their films of oil unite in the space to which they are driven by the lifting force of water displacement, the

<sup>25</sup> Johnson, R. H., The accumulation of oil and gas in sandstone, *Science*, vol. 35, pp. 458-9, 1912.

oil films will aggregate because of surface tension into drops which will further coalesce into fluid masses separating the gas above from the water below. It is, of course, true that the volume of gas required is many times the volume of oil which it would lift in this way but recognizing the limitations upon the process it nevertheless seems potent to accomplish important results in the migration of petroleum.

*Movements of underground water; nature of the movement*

Movement of the water beneath the surface of the earth necessarily involves movement of the oil or gas which may be in its path. Underground water, a term used to comprise all aqueous solutions beneath the earth's surface, includes water from many sources and under many various conditions.<sup>26</sup> Much of it is seepage, fresh or salt water, which has filtered downward from the surface; some is connate, fresh or salt water buried with sediments; while a small part of it is juvenile, primitive fluids expelled from molten magma or igneous rock by crystallization or heat. Above the water-table—below which most openings in the rocks are filled with liquids—underground water is in more or less constant motion from higher to lower levels. Below the water table, motion is in general slower, and great volumes of water may for motion periods remain practically stagnant. The direction of motion is there determined by pressure and is from places of greater to places of lesser pressure or hydrostatic head. This frequently results in an upward creep and lateral oscillation.

The chief causes of movement of water below the water-table are (a) gravity, expressed in the familiar statement that water tends to seek its own level; (b) changes in temperature which may result from the earth's general heat, from the heat of crustal movements, involving crushing or friction, from chemical reaction, or from igneous intrusion; (c) compacting of rocks by burial, or expansion of rocks following erosional stripping of

<sup>26</sup> R. A. Daly, Genetic classification of underground volatile agents, Econ. Geol., vol. 12, pp. 487-504, 1917.

covering; (d) expulsion of juvenile water from igneous masses during crystallization; (e) expansion of gas which may be either of abyssal origin or newly formed by pressure upon organic materials at moderate depths.

Washburne infers

a small, but locally active, very slow, outward creep of the rock fluids (liquid or gas or both) due to pressure from below. The principal reason for the inference is based on plotting the distribution of pressures in the sands of different fields of the United States and of Canada for which data are available. The data are not sufficiently complete to warrant final conclusions, but there are many instances in which the downward increase of pressure between sands, and the increase above the surface pressure, exceed the corresponding hydrostatic head. . . . It seems significant that excess pressures are most common in the more fractured regions, such as Baku and the Gulf Coast, where the deep communication appears to be more open than elsewhere. Other arguments for this ascent are found in the excess temperatures in oil fields, in the distribution of oils and gases of filtered and unfiltered types, in the excess of chlorine in the associated water, and in the abundance of helium in the deep wells of Kansas.<sup>27</sup>

#### *Effect of movement upon accumulation of oil*

The chief contribution of ground water circulation to the underground accumulation of oil and gas in commercial quantities is probably made as a conditioning rather than as a causal agent. Movement of subterranean fluids may assist in overcoming the adhesion and inertia of oil globules, which might otherwise prevent differences in specific gravity from accomplishing gravitative sorting. Johnson<sup>28</sup> states, for example, that differences in specific gravity, and in capillary action seem remarkably impotent when everything is at rest, but that assisted by a little movement these differences bring about very important results. If oil-soaked sand is placed in the middle of a horizontal tube and water-soaked sand is placed at either end, the tube may remain at rest a very long time without any

<sup>27</sup> Washburne, loc. cit., p. 956.

<sup>28</sup> R. H. Johnson, Discussion of Capillary concentration of gas and oil, Am. Inst. Min. Eng., Trans., vol. 50, pp. 842-843, 1915.

appreciable change in the relative position of oil and water. But with a little motion that oil will gradually be distributed above the water along the upper side of the tube. It does not appear to be necessary to have very extensive movement, but some degree of movement is essential.

Or, again, the slow circulation of ground water may permit surface tension phenomena to play a part which would otherwise be denied them. If a body of gas has been segregated above the water in porous sands, circulation or migration of the water may bring globules of oil to the surface of contact between gas and water. If so, these will be held on the surface of the water by its tension. The oil will first spread as a film along the gas-water surface and any oil which is brought in contact with this film must join it. In this way oil may accumulate above water in any subterranean reservoir in spite of the slight difference in specific gravity between the two fluids. "Any movement of the water in the sand, which would in time bring the various parts of the water in contact with its upper surface, would carry bodies of oil of all sizes to the water-gas surface, where surface tension would retain them permanently."

Rich believes that the

principal cause of the migration of oil and gas is the movement of underground water which carries with it minute globules of oil and bubbles of gas, possibly as fast as they are formed. Accumulation results from the selective segregation of oil and gas, which, on account of their buoyancy, always tend to work their way upward as they are carried along and are caught and retained in anticlinal or other suitable traps.<sup>29</sup>

#### *Gas expansion*

Destructive distillation of organic matter, animal or vegetable, under conditions such as those commonly occurring within the body of the earth where free access of air is precluded, produces hydrocarbon gases as well as liquid hydrocarbons. The process

<sup>29</sup> John L. Rich, Moving underground water as a primary cause of the migration and accumulation of oil and gas, *Econ. Geol.*, vol. 16, pp. 347-371, 1921.

is a biochemical one, effected largely by the action of anaerobic bacteria before the deposits are deeply buried or the formation firmly consolidated. But later, if the same beds are covered with thick accumulations of younger sediments, gas may be formed as a result of the action of heat upon the entombed organic matter, liquid or solid. This thermochemical process<sup>30</sup> is accompanied by polymerization of the oil and may be furthered by the increase in pressure resulting from burial. The two kinds of action are mutually complementary; the first mentioned dwindles to nothingness as the second increases in effectiveness; the first is long continued, but the second knows no time limit. Consequently, new gases are produced long after the petroliferous beds are more or less completely sealed by water-saturated "cover rocks."

To these organic gases, there may possibly be added in some localities a modicum of abysmal gas, inorganic in origin, slowly ascending from the deeper interior. The presence of argon and helium among the gases from the deeper sands of Kansas may be thus explained. But regardless of any possible inorganic contributions, these lighter hydrocarbons may be formed under all conditions of temperature and pressure, including those far above their critical temperatures and pressures, so that they may be in that state of matter where the true distinction between gas and liquid disappears.

Gas expansion, if permitted by local physical conditions, will drive fluids, petroleum or water, out of the larger openings in the rocks more readily than from the smaller ones where viscosity and capillarity tend to retain liquids. Relief of pressure at any point or along any plane may result in the migration of oil and water in front of the expanding gas. The result would frequently be scattering of oil rather than concentration, but upward movement would be favored, for relief of pressure would more commonly come from that direction. Hence, here

<sup>30</sup> R. H. Johnson, The rôle and fate of the connate water in oil and gas sands. *Am. Inst. Min. Eng., Bull. No. 98*, pp. 221-226, 1915; *Trans.*, vol. 51, pp. 587-610, 1916.

is another cause tending toward the elevating of oil, if not toward the top of any subterranean reservoir, at least toward the surface of the earth.

Mills has recently<sup>31</sup> called attention to the importance of the escape of gas with entrained oil through fissures as a factor in the migration and accumulation of oil in many faulted areas. Both experimental and field data seem to indicate that "oil is propelled more effectively than water by the propulsive force of absorbed gas. Immediately upon the release of pressure, the absorbed gas expands and propels the oil from within. The comparatively high absorption capacity of oil and its tendency to remain entangled with the flowing and expanding gas appears to be largely responsible for this effective propulsion." Such migration of gas and oil in fault or other fissures "has been upward either to the surface or from one bed to another. Fissuring has also facilitated the lateral migration of oil and gas through porous beds toward these points of escape."

#### *Earth movements; folding and faulting*

The accumulation of strain within the earth's crust may exceed the resisting strength of the strata and necessitate adjustments by folding or faulting movement. In so far as these adjustments involve decrease or increase of reservoir volume, they may result directly in the transfer of oil or gas from place to place. If *similar folds*<sup>32</sup> are formed, the beds will be compressed and thinned on the limbs of anticlines and synclines, but thickened and expanded on the crests and in the troughs of the folds. The result will be a tendency toward the migration of interstitial fluids from the place of compression to the places of lesser pressure—the crest of an anticline or the bottom of a syncline. The balance between folding movements competent to cause such migration and those which would cause regional dynamic alteration sufficiently complete to volatilize all the

<sup>31</sup> R. Van A. Mills, Natural Gas as a factor in oil migration and accumulation in the vicinity of faults, Bull. Am. Assoc. Petroleum Geologists, vol. 7, pp. 14-24, 1923.

<sup>32</sup> C. K. Leith, Structural Geology, Henry Holt & Co., New York, 1913, p. 106.

lighter distillates from the petroliferous substances is, however, so delicate that it is doubtful if folding movements have contributed largely to the accumulation of oil in economic amounts.

Indirectly, folding and faulting of the earth's crust may have materially assisted in the migration and segregation of oil by providing that element of motion which seems essential to the effective operation of such motive forces as capillary action and gravitative assortment. The frequency of earthquake vibrations is suggestive of the repetition of jarring shocks which may have operated to overcome adhesion and inertia which were militating against gravitative assortment of oil and water.

Similarly, the development of fault fissures may afford channels for the escape of compressed gasses, and thus be the indirect cause of migration and accumulation of oil impelled by expanding gas, as noted in the preceding section.

### *Body tides*

Regularly recurrent oscillatory movements within the body of the earth are caused by the attraction of sun and moon. Experiments undertaken to determine the rigidity of the earth by tidal observations indicate<sup>33</sup> that the water tides are of much less amplitude than they would be if the earth were absolutely rigid, and that in fact three- or four-tenths of the tidal strain is compensated by tides within the earth's body. These movements may be compared to the kneading to which a baker subjects dough. They would in general result in an upward migration of earth fluids because as the liquids are squeezed out they would move, if possible, in the direction of least pressure. This kneading of the earth, like the less regular folding and faulting movements, has probably been an important contributing cause of oil and gas migration, notably assisting the operation of other forces.

### THE PROBABLE HISTORY OF MOST OIL AND GAS ACCUMULATIONS

Having thus reviewed the possible causes of the migration of oil and gas, the probable history of the majority of the great

<sup>33</sup> A. A. Michelson, Preliminary results of measurements of the rigidity of the earth, Journ. Geol., vol. 22, pp. 97-130, 1914.

commercial accumulations of these substances may now be sketched. Variations in the relative importance of the different factors involved may of course be expected because of the fact that each oil or gas field is actually unique in its composite features, but the general story needs only slight changes in its major outlines to make it apply to most fields.

Distillation, at first dominantly biochemical and later dominantly thermochemical, begins with the entombment of organic matter in muds, clays and silts. With continued accumulation of interstratified sandy and muddy layers, the oils and gases thus formed are squeezed out of the finer into the coarser sediments. Differential capillary action draws water into the finer openings while the volatile hydrocarbons move into the larger ones. Thus, transverse migration from the shale birth-place of petroleum to the reservoir sands and sandstones takes place. Circulation of subterranean fluids and movements of the earth's body all contribute to this movement from one layer to an adjacent one; whenever oil or gas enters coarsely porous portions of the earth's interior, completely enclosed by water-saturated fine-grained rocks, there it must remain. Transverse migration is never complete; the shales invariably retain more or less of the petroleum which originates therein; it is more nearly complete where there are several sandy layers interbedded at frequent intervals within the shale series than where the same amount of sand is concentrated into a single formation.

Oil and gas which enters coarsely porous strata, sandstones or limestones, will move more or less completely to the pores above those occupied by water within the reservoir. If the rocks are saturated with water, differences in specific gravity, molecular forces, ground water movement, etc., will lift the hydrocarbons to the top of the reservoir and segregate them beneath fine-grained strata or portions of strata. If the reservoir roof is sufficiently inclined, the upward force will be resolved into lateral movement which in most cases will be parallel to the bedding of the rocks. This obliquely upward migration will be stopped where the oil or gas is trapped by changes in the pitch of the reservoir roof. Hence, a knowledge of the shape of the

reservoir is a prime essential to wise exploitation of petroleum accumulation. If, on the other hand, the reservoir is only partly filled with water, oil should be accumulated above the water surface, unless the pores are of capillary dimensions (for oil) in which case it will be broadly disseminated through that portion of the reservoir which is devoid of water. Hence, knowledge of the water conditions and the porosity of the reservoir rocks are likewise of first importance to the petroleum engineer. Lateral migration does not necessarily require an upward component, especially if it is due to gas expansion, but, because of the general prevalence of water in a more or less static condition within the strata from which oil and gas are obtained, it probably has nearly everywhere proceeded in an obliquely upward direction. Its results in concentrating oil and gas in certain parts of the reservoirs will depend chiefly upon their shape.



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Volume XXIV, No. 5



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## JOURNAL OF THE SCIENTIFIC LABORATORIES

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Granville, Ohio

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TRICHOPTILUS PYGMAEUS WLSM.  
AND  
THE NEURATION OF THE FAMILY PTEROPHORIDAE

A. W. LINDSEY

When "The Pterophoridae of America, North of Mexico" was published, two specimens of *T. pygmaeus* were available to the authors, one in the collection of the United States National Museum and the other in the Fernald collection from the type lot. It was gratifying, therefore, to receive from Mr. E. H. Blackmore a series of ten specimens taken at Shawnigan, Vancouver Is., July 18, 1923. This is but one of many valuable results of Mr. Blackmore's diligent collecting and careful study for which the writer expresses his hearty appreciation and thanks.

An examination of the specimens corroborated Mr. Blackmore's identification. The opportunity which they furnish for the accurate determination of the generic characters of *Trichoptilus* has apparently not been enjoyed by anyone else, excepting possibly Lord Walsingham himself, for Professor Fernald had not removed the wings from the single specimen now in his collection, and there is no reason to believe that others exist where they are available for scientific scrutiny. Mr. T. Bainbrigge Fletcher (in litt.) states that he uses *Buckleria* Tutt for the other species commonly placed in the genus, retaining *Trichoptilus* for its type alone. His reason, ample, to be sure, is that Lord Walsingham compared the species concerned and agreed with his views. In order to settle this point, the right wings of one specimen were removed and mounted for microscopic examination, and this led to the surprising results here recorded.

The first wings prepared showed only a single long vein running to the tip of the second lobe of the primaries, apparently  $M_3 + Cu_1$ , according to later discoveries. They were otherwise similar to those of *T. lobidactylus* Fitch excepting the evanescent tips of  $R_2$  and  $R_1$  and bases of both anals. The complete loss of a vein from the second lobe seemed to justify the separation of the genera as practiced by Mr. Fletcher, but to my surprise, other

specimens showed variations in neururation. One had  $Cu_2$  well marked, tubular, though weak, but this specimen lacked  $R_1$ . Other wings were then examined which showed no trace either of  $R_1$  or  $Cu_2$ . The figure (Text fig. 1) is therefore a composite showing all veins known to appear in this species. It will be seen that it differs so little from the wings of other species now

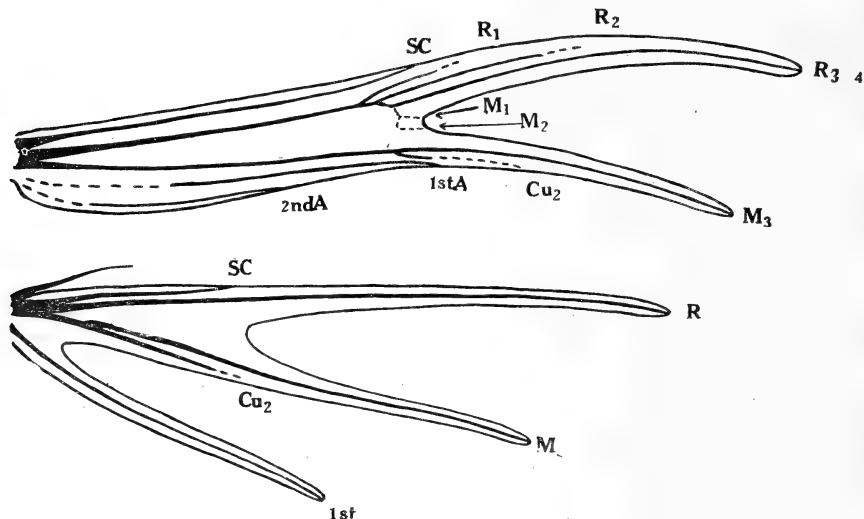


FIG. 1. TRICHOPTILUS PYGMAEUS WLSM NEURURATION.

included in the genus (Plate XX, fig. 1) that the retention of the present association is justified. The condition of the neururation indicates, however, that *pygmaeus* is in a state of evolution which may ultimately produce a much simpler wing than is now found in the species.

In consideration of the diversity of genitalic structure exhibited by the North American species, no analysis of relationships can be drawn from this source. The genitalia of *pygmaeus* are figured (Text fig. 2) for specific identifications. The figure is taken from a camera drawing of a prepared specimen which was slightly distorted on the slide. No appreciable asymmetry is actually present.

It occurred to the writer while working on the wings of this species that the neururation of the Pterophoridae as treated by Meyrick in the Genera Insectorum and by Barnes and Lindsey in the Pterophoridae of America is probably incorrectly interpreted. Our North American genera furnish enough types of neururation to illustrate the problem nicely, and Plate XX, a re-

production of Plate XLVIII of the Pterophoridae of America, shows examples of each genus. The writer is indebted to Dr. Wm. Barnes for the use of the cut for this plate.

In Fig. 10 are shown the wings of the only North American species without clefts. It will be noted that  $R_5$  reaches the apex



FIG. 2. TRICHOPTILUS PYGMAEUS WLSM GENITALIA.

of the primaries,  $M_1$  and  $M_2$  are weak,  $M_3$  and  $Cu_1$  are long stalked, and 1st and 2nd A vestigial. This suggests that some veins may be lost by independent reduction and others by progressive anastomosis, as is so often the case in the Lepidoptera. In the secondaries vestigial veins are even better illustrated, and one median, probably  $M_2$ , is completely lost.

The problems suggested by the comparison of wings of the cleft-winged genera are mostly simple.  $M_1$  and  $M_2$  are usually faintly evident as thickened lines at the base of the cleft in the primaries, and in *Oidaematophorus* alone of our genera is one of them,  $M_1$ , tubular.  $M_3$  persists, showing a tendency to stalking with  $Cu_1$ . In no example is there evidence of extreme coalescence of these veins which would suggest incipient coincidence. On the contrary *Adaina* shows both  $Cu_1$  and  $Cu_2$  in a vestigial state, indicating the limitation of coalescence of the former with  $M_3$  and the reduction of both cubital branches by independent change. Unfortunately none of our genera in the Oidaematophorid series (Spuler's Pterophorinae), including the genera with two anals in the secondaries, appear to be derived from this genus, so the possible results cannot be followed out. In the remaining genera

there is nothing to show the fate of the cubitals except several degrees of stalking of  $Cu_1$  and  $M_3$ , the complete loss of one branch in *Trichoptilus*, and the complete or partial loss, by independent reduction, of the remaining branch in *T. pygmaeus* Wlsm.

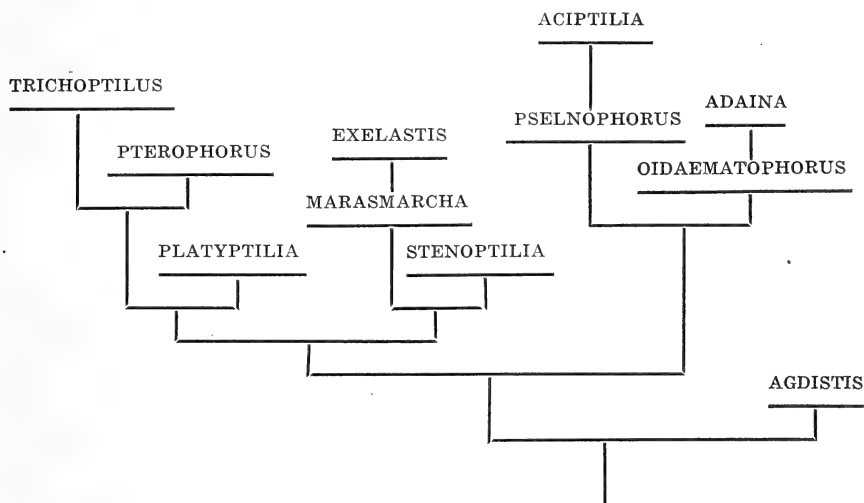
The radius of the primaries is the one other vein whose history is complex. The fact that its fifth branch runs to the apex of the wing in *Agdistis* but ends behind the apex in all of the cleft-winged genera where it is indubitably present, suggests fundamental separation of these lines, as has long been the writer's view. A significant fact regarding this vein is that no genus retaining five branches of the radius has the fifth stalked with another, although the third and fourth are frequently stalked, (and the second with them in some specimens of *Pselnophorus belfragei* Fish, with only four branches remaining). In the genera retaining only four branches of the radius, several things may be noted. First, when the posterior branches are stalked, the most posterior ends in the apex of the wing, both conditions suggesting that it is  $R_4$  or a complex including this vein. Second, when the most posterior branch of the four is not stalked, it ends behind the apex, and excepting *Oidaematophorus*, is preceded by stalked branches, both conditions suggesting that it is  $R_5$ . Third, when  $R_5$  as thus interpreted is present, it appears that the progressive anastomosis of  $R_2$ ,  $R_3$  and  $R_4$ , actually visible in a series of *P. belfragei* Fish, has resulted in the coincidence of two branches. These would naturally be the two showing the earliest and most prevalent tendency to unite, viz.,  $R_3$  and  $R_4$ , and the vein ending in the apex of the primaries must be  $R_3+4$ . This is a condition such as seen in the wings of *Pterophorus periscelidactylus* Fitch. (Fig. 2)

In *T. pygmaeus* Wlsm. three radial branches at the most are present, and the first two show partial reduction without stalking. Apparently then both  $R_1$  and  $R_2$  may be lost in this way. The writer's previous association of the genus, phylogenetically, with *Pterophorus* (*Oxyptilus*) cannot stand, since in the latter  $R_2$  is invariably stalked. Meyrick's diagnosis of *Trichoptilus* states, however, that  $R_2$  may be stalked. This would indicate that some of the exotic species, not available to the writer for examination, represent a different line of evolution which may properly be derived from *Pterophorus* (*Oxyptilus*).

The condition of the veins in some of the more specialized genera, of which *Aciptilia* is the most extreme, is one which can-

not be satisfactorily interpreted without studies of the tracheation of pupal wings. The single vein in the first lobe of the primaries of this genus may be  $R_2+3+4$ , with  $R_1$  independently lost, or  $R_3+4$  with both  $R_1$  and  $R_2$  independently lost.

This interpretation of neururation together with the characters found in other parts of the body modifies the writer's former opinions of the phylogeny of the North American genera as expressed in the Pterophoridae of America (Diagram, p. 286). In addition to actual differences between existing genera, it now seems unlikely that so many of these genera represent the ancestry of others. Rather than this, they seem to be derived from common ancestors in most cases. The following diagram expresses the writer's modified view of the phylogeny of our genera.



In order to correct the inaccuracies which crept into the key to North American genera in the Pterophoridae of America, the following key has been prepared. It has been found impossible to construct a key without falling back on neururation at some point, therefore it has been used freely to produce an accurate key. The wings may easily be examined as transparent objects without denuding or bleaching if they are mounted in pure alcohol on a microscope slide, and all veins and thickened lines then become visible.

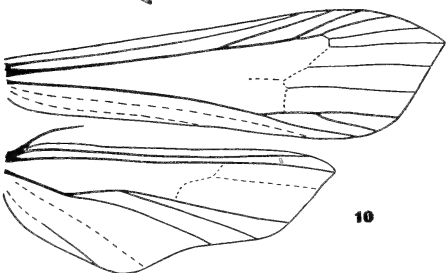
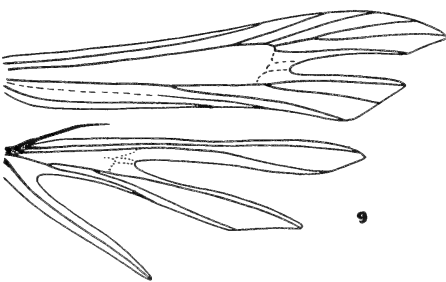
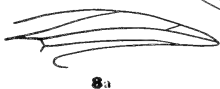
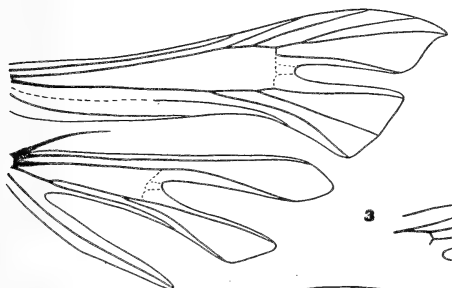
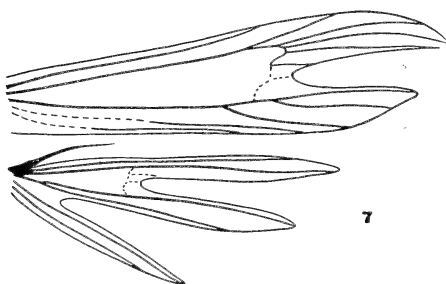
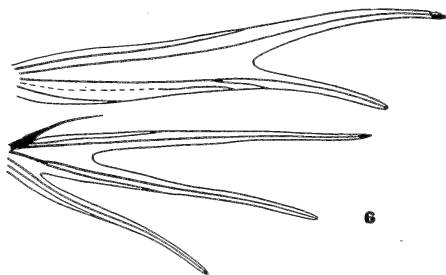
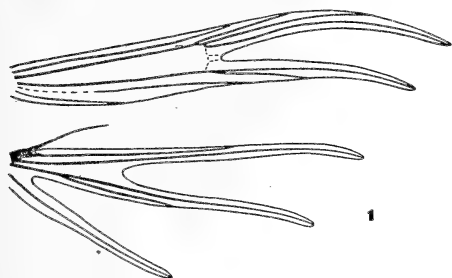
KEY TO THE NORTH AMERICAN GENERA  
OF PTEROPHORIDAE

- |  |                        |
|--|------------------------|
| 1. Wings entire .....  | <i>Agdistis</i>        |
| Wings cleft .....  | 2                      |
| 2. Radius of primaries with four branches or less .....  | 3                      |
| Radius of primaries with five branches .....   | 10                     |
| 3. Primaries with only one or two veins in second lobe, anal excepted; deeply cleft, with slender lobes .....                        | 4                      |
| With $M_2$ , $Cu_1$ and $Cu_2$ all present .....   | 5                      |
| 4. Two or three branches of radius present .....   | <i>Trichoptilus</i>    |
| Only one radial .....  | <i>Aciptilia</i>       |
| 5. Primaries with all branches of radius free .....  | <i>Oidaematophorus</i> |
| Some branches stalked .....  | 6                      |
| 6. With a free vein ( $R_5$ ) behind the stalked branches of the radius, ending behind apex of first lobe .....                      | 7                      |
| The last branches of the radius stalked .....  | <i>Pselnophorus</i>    |
| 7. Secondaries with a tuft of black scales near tip of third feather .....   | <i>Pterophorus</i>     |
| No such tuft .....   | 8                      |
| 8. Second lobe of secondaries with two veins .....   | <i>Adaina</i>          |
| With three veins .....   | 9                      |
| 9. Fringes of inner margin of third lobe of secondaries with a few scales, sometimes faint in our species .....                      | <i>Exelastis</i>       |
| Without such scales .....  | <i>Marasmarcha</i>     |
| 10. $R_2$ , $R_3$ and $R_4$ stalked .....  | <i>Pterophorus</i>     |
| $R_3$ and $R_4$ alone stalked .....  | 11                     |
| 11. Secondaries usually with black scales in fringes of inner margin. Anal angles of both lobes of primaries usually prominent ..... | <i>Platyptilia</i>     |
| Without black scales. Anal angles present but retreating .....   | <i>Stenoptilia</i>     |

PLATE XX

Neuration of Pterophoridae.

1. *Trichoptilus lobidactylus* Fitch.
2. *Pterophorus periscelidactylus* Fitch.
3. *Platyptilia carduidactyla* Riley.
4. *Pselnophorus belfragei* Fish.
5. *Adaina zephyria* B. & L.
6. *Aciptilia walsinghami* Fern.
7. *Oidaematophorus lithodactylus* Tr.  
(Genotype, European)
8. *Marasmarcha pumilio* Zell.
- 8a. *Exelastis cervinicolor* B. & McD.  
(First lobe of primary)
9. *Stenoptilia pterodactyla* Linn. (Genotype).
10. *Agdistis americana* B. & L.



A. W. LINDSEY

NEURATION OF PTEROPHORIDAE



## NOTES ON AMERICAN PALEOZOIC CEPHALOPODS

AUG. F. FOERSTE

### INTRODUCTION

The writer has been engaged for a number of years on an intensive study of Ordovician and Silurian cephalopods with special reference to those of American origin. The study is far from complete. A large quantity of the available material has not yet been examined, and some of that already studied must be re-examined in the light of later observations. Research of this sort is greatly expedited by the helpful criticism of others interested in the same field; but in the absence of published reports of progress, such assistance is limited to that secured at occasional meetings. Moreover, it is desirable to reduce to printed form some of the results thus far obtained, in order that they may be available for use in other studies. The following notes are accordingly a miscellaneous gathering, in part intended to invite criticism, and in part intended to report progress, especially along the line of generic relations.

The conclusion has been reached that Ozarkian and Canadian cephalopods were largely holochoanitic in structure and that the first ellipochoanoidal cephalopods were of Chazyan age. In holochoanoidal cephalopods the septal necks extend downward so that each is in contact with the upper margin of the neck beneath, into which it invaginates without connecting ring or sheath. The septal necks of ellipochoanoidal cephalopods are short, and successive necks are connected by ring-like segments, called connecting rings or sheaths. Frequently these connecting rings have failed of preservation and then only the unconnected septal necks may be seen. In other specimens, especially those of Actinoceroids, the septa likewise are wanting, but the siphuncle remains, reinforced by interior calcareous deposits.

Certain species of cephalopods almost or quite invariably lack all trace of connecting rings. Probably in these species the membrane which ordinarily secreted the calcareous material either formed only a very thin deposit or none at all.

Such holochaoanitic genera as *Endoceras*, *Cameroeras* and *Piloceras* have siphuncles built by successive septal necks which extend downward until each invaginates into the neck next beneath. Within the camerae this type of neck generally has a concave vertical outline. The septal necks of *Clarkoceras*, *Eremoceras*, *Ellesmereoceras* and *Protocycloceras*<sup>1</sup> have vertical outlines similarly concave. Ruedemann has shown corresponding structures in *Protocycloceras*, *Orygoceras* and *Cyclostomiceras*.<sup>2</sup> A recent examination of all the orthoconic and crytoceraconic species described by Billings from the Canadian, indicates that concave vertical outlines prevail in all the specimens which reveal the structure of the siphuncle. The typical Black River form of *Cyrtocerina* has an ellipchoanoidal structure, but the siphuncle of the Canadian species *Cyrtocerina mercurius*, presents segments with concave vertical outlines, thus indicating that it is really a *Clarkoceras*. In the numerous species of "*Orthoceras*" described by Billings, concave vertical outlines prevail along the segments of the siphuncle within the camerae.

Apparently the structure of the Canadian orthocones and crytoceracones is prevailingly that of the holochaoanitic cephalopods. Corresponding ellipchoanoidal genera make their appearance in Chazyan time, though such holochaoanoidal genera as *Endoceras* continue through that epoch into later stages. If these observations are verified by increasing knowledge of Ozarkian and Canadian cephalopods, they would suggest that the interval between the Canadian and Chazyan stages was one of the most important in geologic history, sufficient to admit of a major change in the structure of cephalopods. If corresponding changes are found in other groups of animals, contrasting those of Canadian age with those of Chazyan and later times, the separation of Canadian strata from the Ordovician system would seem as fully warranted by paleontology as by stratigraphy.

The enormous number and variety of species which have been referred to the genus *Orthoceras* has always been a serious problem to the systematist. Barrande grouped his numerous species into various divisions based on surface ornamentations. Hyatt has proposed generic names for the major groups. Later, Hyatt

<sup>1</sup> Foerste, A. F., Notes on Arctic Ordovician and Silurian cephalopods; Journ. Sci. Lab. Denison Univ., vol. 19, pp. 261-271, 1921.

<sup>2</sup> Ruedemann, R., Cephalopoda of the Beekmantown and Chazy formations of the Champlain basin; New York State Museum Bull. 90, pp. 444, 451, 502, 1906.

attempted in Zittel-Eastman's Text-book of Paleontology to introduce diagnostic characters based on internal structure, but apparently without any considerable degree of success.

Although the generic names introduced by Hyatt have proved very convenient in the past, it is now evident that dissimilar groups are in some cases included under a single generic heading, so that it is probable that further subdivision of this genus is desirable. Before this is done, however, the types of the genera previously proposed must be studied with the view of determining the proper limits to assign to those genera in restricting or subdividing them. Here there are several difficulties. It is practically impossible to determine what species forms the real type of *Orthoceras*, nor is the interpretation of *Cycloceras* clear. Moreover, the genera *Geisonoceras*, *Dawsonoceras* and *Spyroceras*, proposed by Hyatt, must be interpreted from the original type species and not as redefined by Hyatt in the Zittel-Eastman Textbook.

Similar statements apply to the different subdivisions which have been proposed for the genus *Actinoceras*. The name *Sactoceras*, established with a Silurian species for its type, should probably not be discarded for *Loxoceras*, based on a Carboniferous species.

Looking toward a clearer understanding of these cephalopods, the new genus, *Perigrammoceras*, is here proposed to accommodate certain orthoceroids, and a new subdivision of *Actinoceras* is given the generic name, *Elrodoceras*. The familiar species *Trochoceras* (?) *baeri* is made the type of another new genus, *Charactoceras*.

The many species ordinarily assigned to the genus *Oncoceras* are apparently divisible into two groups, one of which is typified by *O. pandion* Hall, while the other is the true *Oncoceras* with *O. constrictum* Hall as its type. For the *O. pandion* group the name *Beloitoceras* is proposed. It was apparently from *Beloitoceras* that *Maelonoceras* was evolved. Either *Beloitoceras* should be considered an independent genus or it should be made a subdivision of *Maelonoceras*. But if the second alternative is chosen, *Maelonoceras* must be used in a broader sense than the customary interpretation based on the genotype, *M. praematurum*.

Another group of conchs, sometimes included in *Oncoceras*, is typified by the species originally described as *Cyrtoceras orcas*

Hall. *C. laterale* and *C. orodes* are closely similar species. For these the term *Amphicyrtoceras* is proposed. Among other forms having about the same characteristics are *Oncoceras futile* Billings, *O. pettiti* Billings and *O. teucer* Billings. *Streptoceras* differs from *Amphicyrtoceras* chiefly in the more triangular outline of the aperture due to the anterior extension of the hyponomic sinus into a sort of lip. It probably was derived from the latter genus. *Poterioceras* is unknown in Silurian strata.

Among gomphoceroid conchs, there is a primitive group, known to be represented in the Richmond and probably present also in earlier strata, which has only a moderate angulation at the hyponomic sinus instead of a strong constriction as in typical *Gomphoceras*. For this group the term *Diestoceras* is proposed, with *G. indianense* as the genotype. This genus also includes *G. obesum* Billings and *G. eos* Hall and Whitfield.

Finally, the generic terms *Westonoceras* and *Cyrtogomphoceras* are here proposed for the very aberrant species, *Cyrtoceras manitobense* Whiteaves and *Oncoceras magnum* Whiteaves.

#### ACKNOWLEDGEMENTS

It is needless to state that it would have been impossible to carry on the studies included in the present publication if it had not been for the good will and generous helpfulness shown by many individuals. I am especially indebted to Dr. R. S. Bassler of the U. S. National Museum; Dr. E. M. Kindle of the Victoria Memorial Museum; Prof. Percy Raymond and Mr. Samuel Henshaw of Harvard University; Dr. Chester A. Reeds and Dr. E. O. Hovey of the American Museum of Natural History; Prof. J. E. Carman of Ohio State University; Prof. Stuart Weller and Mr. Arthur W. Slocom of the University of Chicago; Mr. Henry L. Ward of the Public Museum of Milwaukee; Prof. W. H. Shideler of Miami University; Mr. C. L. Faber of Cincinnati, and Judge Henry Pavey, now deceased, of Hillsboro, Ohio. Without assistance from these individuals, and the loan of specimens from collections under their care, little of permanent value could have been accomplished.

I am under special obligations to Dr. David White and Mr. Walter C. Mendenhall, of the U. S. Geological Survey, for access to the facilities of that Survey, and for giving me every encouragement.

## 1. THE HOLOCHOANITIC CEPHALOPODS OF CANADIAN STRATA

Ulrich included in the Canadian series of strata the Beekmantown of New York, Vermont, and adjacent Canada, the Levis of the Quebec area, the Romaine of the Mingan island area, all but the basal part of the Bretonian of Nova Scotia, the upper part of the Quebec group of Newfoundland, and the approximate equivalent of these strata elsewhere. Those strata which intervene between the Canadian and the typical Cambrian he included in the Ozarkian. The fauna of the Potsdam sandstone is regarded as distinct from the typical Cambrian and as characterizing the basal part of the Ozarkian.

The cephalopod fauna of the Ozarkian and Canadian differs so strongly from that of the overlying Ordovician that it suggests that the interval between the Canadian and the Ordovician is one of the great time-breaks of geology. Very few genera bridge the interval between the Canadian and Ordovician, and these few are represented in the Ordovician by species which usually are strikingly different from those in the Canadian.

Such genera as *Eurystomites*, *Tarphyceras*, *Aphetoceras* and *Trocholiticeras* are, strictly speaking, Canadian. It is possible that an intensive study of *Eurystomites plicatus* and *Eurystomites robertsoni* will reveal differences from the typical Canadian forms of sufficient importance to be at least of subgeneric rank. In *Eurystomites plicatus*, for instance, the segments of the siphuncle enlarge slightly within the camerae, as though short septal necks with intermediate connecting rings were present, while this appearance is not noted in Canadian species. In *Tarphyceras multicameratum*, moreover, the camerae are much shallower and the rate of increase in diameter of the conch is greater. Nothing corresponding to the Canadian species of *Schroederoceras* occurs in the Ordovician of North America. Typical *Schroederoceras*, of course, is European, 8 European species being recognized by Hyatt. Typical *Trocholites* is of Trenton or Cincinnati age, but *Trocholites internistriatus* (Whitfield) occurs as early as the Beekmantown division of the Canadian.

The Canadian species described by Ruedemann under the term *Cyrtendoceras* (?) *priscum* differs from anything known in the Ordovician of America.

Canadian as well as Ordovician and Silurian species have been

referred to the genera *Cyclostomiceras*, *Cyrtocerina*, and *Maelonoceras*, but the Canadian species so referred belong to different genera from those occurring in later strata. In typical *Cyclostomiceras*, of Canadian age, the segments of the siphuncle present concave vertical outlines, while the Niagaran species *Cyrtoeras brevicorne* Hall and *Cyrtoceras orodes* Billings, referred by Grabau and Shimer to *Cyclostomiceras*, belong to a distinct genus with short septal necks and convex connecting rings, for which the term *Amphicyrtoceras* is proposed on the following pages. *Cyrtocerina typica* Billings, from the Black River, has nummuloidal segments in the siphuncle (Plate XLI, Fig. 9) while in *Cyrtocerina mercurius* Billings these segments present concave vertical outlines (Plate XLI, Fig. 8) as in *Clarkoceras*, a genus which seems to be confined to the Canadian. In *Maelonoceras praematurum* (Billings), from the Black River, the segments of the siphuncle are subfusiform, while in *Cyrtoceras metellus* Billings, from the Canadian, these segments are strongly nummuloidal in form, if specimen No. 820a in the Victoria Memorial Museum correctly represents this species.

Such genera as *Eremoceras* and *Piloceras* are confined to the Canadian. In both, the segments of the siphuncle have concave vertical outlines within the camerae.

Concave vertical outlines are presented also by a considerable number of those orthoconic shells which were described by Billings and others from Canadian strata under the generic term *Orthoceras*. In fact, all of the Canadian orthoconic species, concerning which it has been possible to learn the structure of the siphuncle, have siphuncular segments with concave vertical outlines. Of these, the annulated forms are, at present, referred to *Protocycloceras*. Possibly most of the smooth forms will fall under *Ellesmereoceras*.<sup>3</sup> They are characterized, as a rule, by rather closely arranged septa and by siphuncles of more moderate size than in typical *Endoceras*. Orthoconic specimens, with siphuncles more readily comparable with those of typical *Endoceras*, also exist in Canadian strata. In none of the Canadian Endoceroid specimens described by Billings has it been possible to discover the presence of endocones. From this it does not follow necessarily that endocones are absent, since the actual

<sup>3</sup> Foerste, A. F., Notes on Arctic Ordovician and Silurian cephalopods; Journ. Sci. Lab. Denison Univ., vol. 19, p. 265, pl. 27, figs. 3A, B, C; pl. 33, fig. 3, 1921.

number of specimens which expose well the interior of the siphuncle is relatively small. However, when the genus *Ellesmereoceras* was described, the absence of endocones was regarded as one of its characteristic features.

*Orygoceras* is another orthoconic Canadian genus with siphuncular segments presenting concave vertical outlines. The conch displays a smooth exterior, but an annulated interior.

Canadian cephalopods are remarkable for the number of genera and species in which the segments of the siphuncle present concave vertical outlines. Such outlines are characteristic of the holchoanitic cephalopods, in which the septal necks are prolonged downward at least the height of one of the camerae.

In Zittel-Eastman's Text-book of Paleontology the Holchoanites include the genera *Vaginoceras*, *Cameroceras*, *Endoceras*, *Nartheoceras*, *Nanno*, *Piloceras*, and *Cyrtendoceras*. To this list the genera *Cyclendoceras* and *Clarkoceras* have been added by Bassler.<sup>4</sup> Ruedemann recognized the holchoanitic structure of the siphuncle of *Protocycloceras*,<sup>5</sup> his illustrations show the concave vertical outlines of the siphuncular segments of *Cyclostomiceras*. His vertical section of *Orygoceras* indicates a similar structure. The present writer has described the concave vertical outlines of the siphuncular segments of *Eremoceras* and *Ellesmereoceras*, and in the present bulletin he calls attention to similar structure in various orthoconic cephalopods described by Billings from Canadian strata.

Although it does not follow necessarily that species with siphuncular segments having concave vertical outlines are holchoanoidal in structure, the writer believes that such a relationship exists. Should this prove to be true, after further investigation, then it follows that the chief characteristic of Canadian orthoconic and cyrtconic cephalopods is the remarkable dominance of holchoanitic forms.

Although such holchoanitic genera as *Cameroceras*, *Cyclendoceras*, *Endoceras*, *Nartheoceras*, *Nanno*, *Suecoceras*, and *Vaginoceras* are well represented in Ordovician strata, they here are associated with numerous Orthchoanitic and Cyrtchoanitic forms which are either rare or absent in Canadian strata. The

<sup>4</sup> Bassler, R. S., Bibliographic Index of American Ordovician and Silurian fossils; U. S. Nat. Museum Bull. 92, 1915.

<sup>5</sup> Ruedemann, R., Cephalopoda of the Beekmantown and Chazy formations of the Champlain basin; New York State Museum Bull. 90, p. 441, 1906.

Canadian, in brief, is characterized by the dominance of holochoanitic cephalopods, and the early Ordovician by the influx of numerous Orthochoanitic and Cyrtchoanitic cephalopods.

It should be noted that in some of the Canadian genera of cephalopods, here cited as having concave vertical outlines, this concavity is so faint that their outlines are described more readily as straight than concave; but they are distinctly not convex. This is true, for instance, of the species originally described as *Cyrtoceras quebecense*.

## 2. SMOOTH ORTHOCONIC CANADIAN CEPHALOPODS

Most of the smooth orthoconic cephalopods found in the Canadian strata in Canada have the siphuncle in contact with the ventral wall of the conch. The sutures of the septa of *Orthoceras sordidum* Billings curve downward distinctly on the ventral side of the conch, as in the specimen figured by Ruedemann<sup>6</sup> from Fort Cassin, Vermont, under the name *Endoceras montrealense*. The septal necks extend downward the length of one camera and present a concave vertical outline within the camerae. Similar septal necks are found in *Orthoceras montrealense* Billings and *Orthoceras glaucum* Billings. These species are alike in the small height of their camerae. In this respect they resemble *Ellesmereoceras scheii* Foerste, to which they may be closely related.

In *Orthoceras indagator* Billings the structure of the siphuncle is more like that of typical *Endoceras*. While the general vertical outline of the septal necks is concave within the camerae, the lower end of these necks curves inward to invaginate within the upper part of the neck next beneath. The upper part of the siphuncle of one specimen, numbered 7454 in the Victoria Memorial Museum, appears to contain an endocone. Apparently *Orthoceras indagator* is one of the earliest known forms of typical *Endoceras*, a genus common in the Chazyan.

Nothing is known of the structure of the septal necks in *Orthoceras sayi*, *O. autolytus*, *O. veterator* or *O. perseus*, all described by Billings from Canadian strata, with the possibility of *O. autolytus* having been derived from Ozarkian strata, since it occurs in conglomeratic layers. Of these species, *Orthoceras sayi* has such a large siphuncle that it resembles typical *Endoceras* in

<sup>6</sup> Ruedemann, R., op. cit., p. 424.

transverse sections. In the other three species the siphuncles are relatively smaller and the camerae are closely crowded, as in *Ellesmereoceras*. It will require vertical sections of the types to determine their affinity with any confidence.

The siphuncle of *Orthoceras atticus*, *O. becki* and *O. explorator*, all described by Billings from Canadian strata, is not in contact with the ventral wall of the conch, but is between the ventral wall and the center. The siphuncle of *O. atticus* was described by Billings as "not much, if at all, inflated between the septa." That of *O. explorator* is described as cylindrical. In none of the three species is the structure of the siphuncle known with sufficient accuracy to determine whether it belongs to the group with long septal necks, as in the Endoceroids, or to the group with short septal necks, as in the Orthoceroids.

So far, no orthoconic cephalopods have been found in Canadian strata of which it is known with certainty that they belong to the Orthoceratida rather than to the Endoceratida. On this account it would be desirable to investigate all known Canadian orthoconic species with the object of determining the structure of their siphuncles. It is evident that if typical Orthoceratida should prove absent in Canadian and Ozarkian strata, this fact would be of great service in identifying the horizon of some of the lower Paleozoic formations.

The single specimen of *Orthoceras primigenium*, figured by Hall<sup>7</sup> from the Canadian near Fort Plain in the Mohawk valley of New York, has a conch estimated to have been about 18 or 19 mm. in diameter at its lower end, enlarging possibly to 22 mm. at its upper end. A thickness of only 2 to 3 mm. of one side of the conch remains. There is no trace of annulation of the surface of the shell. The specimen consists of a living chamber 14 mm. in height above the suture of the uppermost septum. On the left margin of the specimen 12 camerae occur in a length of 9 mm. The two uppermost camerae are distinctly shallower than those beneath, suggesting that the conch had reached full maturity. The concavity of the septa along that part of the specimen which is preserved equals 2 mm.; evidently toward the center of the original specimen this concavity must have been much greater. There the specimen in its present condition is 13 mm. in width, the maximum concavity is 4.5 mm. from the left side, and the

<sup>7</sup> Hall, J., Pal. New York, vol. 1, 1847, pl. 3, fig. 11.

septa rise 2.5 mm. higher on the right side than on the left. This indicates that the sutures of the septa are oblique, and that the siphuncle probably was located nearer the left side of the specimen, somewhere in that part which has weathered away. On the right side of the specimen the septa are more closely crowded, suggesting that, notwithstanding the general orthoconic aspect of the specimen, it may have been somewhat cyrtconic in structure. There is no evidence that this single specimen is even congeneric with the small apical ends of orthoconic shells figured by Hall on the same plate (Fig. 11a).

### 3. ELLESMEREOCERAS FOERSTE

Genotype: *Ellesmereoceras scheii* Foerste. Journ. Sci. Lab., Denison Univ., vol. 19, p. 265, pl. 27, figs. 3 A, B, C.; pl. 33, fig. 3, 1921

The genus *Ellesmereoceras* was founded on the belief that there was a group of Endoceroids in which endocones were absent. If eventually it should be proved that endocones were present, the value of this generic term would be questionable. In most of the species having the general appearance of *Ellesmereoceras* the vertical outlines of the septal necks are distinctly concave, but there is no clear evidence of the invagination of the lower part of these necks into the upper part of the neck next beneath, as in typical *Endoceras*. The camerae usually are closely crowded.

This type of structure appears to be characteristic of Canadian strata, but may have originated in Ozarkian times.

Holochoanitic cephalopods with endocones are known to be present in the Ozarkian, and are under investigation by Dr. E. O. Ulrich.

### 4. PROTOCYCLOCERAS HYATT

Genotype: *Orthoceras lamarcki* Billings. Canadian Nat., vol. 4, 1859, p. 362; Foerste, Journ. Sci. Lab. Denison Univ., vol. 19, 1921, p. 268, pl. 33, figs. 7 A-D

*Protocycloceras* was established by Hyatt to include annulated orthoceracones and cyrtoceracones without longitudinal ridges but with a large siphuncle.

Ruedemann has shown<sup>8</sup> that in *Orthoceras lamarcki*, the genotype, the septal necks have a length equal to that of one camera, and that within the camerae their vertical outlines are concave. He has also figured a similar structure in *Protocycloceras whit-*

<sup>8</sup> Ruedemann, R., op. cit., p. 440.

*fieldi* Ruedemann.<sup>9</sup> *Orthoceras ordinatum* Billings likewise possesses septal necks with concave vertical outlines within the camerae. In the three species here named the siphuncle is not in contact with the ventral wall of the conch. In all the other annulated orthoconic species described by Billings from Canadian strata, contact of the siphuncle with the ventral wall of the conch prevails.

Nothing is known about the siphuncle of *Orthoceras catulus*, *O. furtivum*, and *O. repens*, beyond the fact that its general form is cylindrical, and that it is in contact with the ventral wall of the conch. All are Canadian species, described by Billings.

In *Orthoceras cataline*, *O. xerxes*, and *O. cato*, also described by Billings from Canadian strata, the conchs are not only annulated but also striated transversely. In all three of these species the septal necks are distinctly concave within the camerae. Transverse striae were not discovered on any of the other Canadian annulated orthocones mentioned in the preceding paragraphs.

In *Orthoceras henrietta* Dwight the conch is strongly annulated. The siphuncle is nearly in contact with the ventral wall and is 1 mm. in diameter where the diameter of the conch is 6.4 mm.

Apparently all of the above species are to be included in *Protocycloceras*.

##### 5. ORYGCERAS RUEDEMANN

Genotype: *Orthoceras cornuoryx* Whitfield. Amer. Mus. Nat. Hist. Bull., 1, 1886, p. 320, pl. 27, figs. 1, 2, 6; Ruedemann, New York State Mus. Bull., 90, 1906, p. 450, pl. 14, figs. 5-8, text fig. 19, 20

*Orygoceras* is described as consisting of conchs which are smooth externally but which internally are annulated. The siphuncle is small and is almost 1 mm. from the ventral wall of the conch. Ruedemann describes the siphuncle as orthochoanitic, the septal necks being short and straight and the remainder of the siphuncle being formed by the intervening connecting sheaths. In his figure,<sup>10</sup> the vertical outline of the segments of the siphuncle included within successive camerae is seen to have been concave. His section passes through the center of the siphuncle in a lateral direction.

<sup>9</sup> Idem, p. 444, figs. 17a, b.

<sup>10</sup> Idem, p. 451, fig. 20.

## 6. CLARKOCERAS RUEDEMANN

Genotype: *Piloceras newton-winchelli* Clarke. Geol. Minnesota, vol. 3, pt. 2, 1897, p. 767, figs. 8, 9; pl. 47, figs. 1-3. Ruedemann, New York State Mus. Bull., 80, 1905, p. 337

*Clarkoceras* proclaims its relationship to the suborder *Holochloanites* not only by the presence of endocones but also by the concave outline of the segments of the siphuncle within the camerae. The septal necks apparently extend the length of one camera. Excellent figures of the structure of the genotype are presented by Clarke. The siphuncle is free from contact with the adjacent wall of the conch.

*Clarkoceras holtedahli* Foerste,<sup>11</sup> from the Canadian of Bache peninsula on Ellesmereland, evidently is congeneric. Here also, the elongated septal necks present concave vertical outlines within the camerae, as in *Piloceras*. The siphuncle is almost in contact with the adjacent wall of the conch.

A similar structure is displayed by the species *Cyrtocerina mercurius* Billings (Plate XLI, Fig. 8), described from the Canadian at Point Lewis, opposite Quebec. This species is related to, but is not congeneric with *Clarkoceras*.

Typical *Cyrtocerina* (Plate XLI, Fig. 9), however, as represented by its genotype *Cyrtocerina typica* Billings, from the Black River (Leray) at Pauquette Rapids, Ottawa river, Canada, belongs to the group *Ellipchoanida*, as originally defined by Hyatt.<sup>12</sup> This group included both the suborder *Orthochoanites* and *Cyrtochoanites* as defined later in Zittel-Eastman's Textbook of Paleontology. Judging from the convex curvature of the segments of the siphuncle within the camerae, the relationship of typical *Cyrtocerina* is with the *Cyrtochoanites*.

Among the various species described by Billings from the Canadian strata of Canada under the name *Orthoceras*, there are two which evidently are related to *Clarkoceras*, although their degree of relationship can not be determined until the conch, as a whole, is known. These species are *Orthoceras missiquoi* and *Orthoceras edax*.

In *Orthoceras missiquoi* the siphuncles are slightly curved, especially toward the apical end. That side of the siphuncle which is concavely curved lengthwise is smooth and a little flat-

<sup>11</sup> Foerste, A. F., op. cit., pl. 27, figs. 2A, B; pl. 33, fig. 1.

<sup>12</sup> Hyatt, A., Genera of fossil cephalopods; Boston Soc. Nat. Hist., Proc., vol. 22, p. 260, 1883.

tened and evidently was in contact with the ventral wall of the conch, so that the location of the siphuncle must have been endogastric, as in *Clarkoceras*. Along the remainder of the contour of the siphuncle the septal necks appear to have equalled in length the height of the camerae, and to have presented vertical outlines within these camerae. In one of the specimens an endocone apparently was present. *Orthoceras edax* shows a similar structure. Both *Orthoceras missiquoi* and *O. edax* are congeneric with *Cyrtoceras quebecense* Whiteaves, described from Point Lewis, opposite Quebec. The conch of the latter species is relatively much more elongated than in typical *Clarkoceras*; the segments of the siphuncle are cylindrical in form, and consist of the septal necks, each of which is one camera in length.

#### 7. EREMOCERAS (HYATT) FOERSTE

Genotype: *Cyrtoceras syphax* Billings. Pal. Foss., vol. 1, Geol. Surv. Canada, 1865, p. 194, text fig. 178. Foerste, Journ. Sci. Lab. Denison Univ., vol. 19, 1921, p. 263, pl. 33, figs. 8 A, B, C; 2

*Eremoceras* is a small subfusiform cephalopod, somewhat like *Cyclostomiceras* in form. The dorsal side of the conch is distinctly convex lengthwise, while the ventral side is almost straight. The camerae are closely crowded. The siphuncle is large, and endogastric in location. It is in contact with the ventral side of the conch for the greater part of its width. In the type specimen, the siphuncle is depressed dorso-ventrally, being considerably more convex along the side facing the interior of the conch. Vertical outlines of the septal necks are curved slightly inward within the camerae, as in the Endoceratida. The genus is known only in Canadian strata.

*Cyrtoceras aristides* Billings may be related to *Eremoceras*. The siphuncle is large and in contact with the adjacent wall of the conch, and the living chamber apparently contracts toward the top. Better specimens than the type are needed for exact reference.

#### 8. CYCLOSTOMICERAS HYATT

Genotype: *Gomphoceras cassinense* Whitfield. Amer. Mus. Nat. Hist. Bull., vol. 1, 1886, p. 322, pl. 29, figs. 1-3. Ruedemann, New York State Mus. Bull., 90, 1906, p. 501, fig. 56; pl. 37, figs. 1-3; pl. 38, figs. 5, 6

Conch subfusiform in outline, the greatest diameter being at or immediately below mid-height of the living chamber. The

lengthwise curvature of the dorsal side is greater than that of the ventral side, and the siphuncle is close to the ventral side, but not in contact with the latter. In this position the siphuncle is said to be endogastric. The segments of the siphuncle present concave vertical outlines within the camerae, as well illustrated by Ruedemann. The septal funnels curve backward a distance equal to one camera.

Only two species of *Cyclostomiceras* are known: *cassinense* (Whitfield) and *C. minimum* (Whitfield); both are confined to the Canadian (Beekmantown) of Vermont.

The relationship of *Cyrtoceras aristides* Billings, of Canadian age, can not be determined in our present knowledge of that species. The living chamber apparently contracts toward the top somewhat as in a small *Cyclostomiceras*, but the siphuncle is rather large. Although the siphuncle is known to be in contact with the ventral wall of the conch, it is not possible to determine from the type in its present condition, imbedded in the matrix, whether its location is endogastric or exogastric. Nothing is known about the structure of the siphuncle.

#### 9. EXOGASTRIC CYRTOCEROIDS OF CANADIAN AGE

The conch of *Cyrtoceras confertissimum* Whitfield is distinctly curved lengthwise and depressed dorso-ventrally. The siphuncle is near the convexly curved side of the conch. According to Ruedemann<sup>13</sup> the septal necks are short and the siphuncular segments are nearly tubular, but very slightly contracted within the camerae. This concave outline of the siphuncular segments is characteristic of the numerous species referred to *Orthoceras*, by Billings and other authors, in Canadian strata. The dorso-ventral depression of the conch, however, is a feature not seen in these so-called Orthoceroids.

In *Cyrtoceras alethes* Billings, which may be of Ozarkian rather than of Canadian age, the conch is moderately curved lengthwise and strongly compressed laterally. The ventral side has a radius of lengthwise curvature of 25 mm. and a radius of lateral curvature of 3 mm. Only 6 camerae are present. If the lengthwise curvature of the ventral side continued along the living chamber the latter would be contracted dorso-ventrally, somewhat as in the species described by Billings from the Black

<sup>13</sup> Ruedemann, R., Cephalopoda of the Beekmantown and Chazy formations of the Champlain basin; New York State Museum Bull. 90, p. 507, 1906.

River of St. Joseph Island under the name *Cyrtoceras huronense*. However, too little of the living chamber is present to determine this with certainty. The siphuncle is in contact with that side of the conch which is curved convexly lengthwise. Its segments may be subfusiform in outline, but not enough is exposed to give a good idea of its structure. The general resemblance of *Cyrtoceras alethes* to such forms as *Cyrtoceras huronense* Billings, *C. isodorus* Billings, *C. pandion* Hall and *C. plebium* is sufficiently great to make it desirable to determine with accuracy whether such an early origin of cyrtoceroids of this type actually took place.

The conch of *Cyrtoceras metellus* Billings is distinctly curved lengthwise and the section is stated to be circular or nearly so. The siphuncle of the type is said to be unknown. Billings stated that this species resembled *Cyrtoceras syphax* Billings very closely; in that case its siphuncle should be located on that side of the conch which is curved concavely lengthwise. However, in the collections of the Geological Survey of Canada, Specimen No. 820a, labelled *Cyrtoceras metellus*, has the siphuncle in contact with the convexly curved side of the conch. The segments are strongly nummuloidal, and, owing to the concavity of the septa, are strongly oblique to the ventral outline of the conch. Moreover, on this specimen the septa rise much higher on the concavely curved side of the conch than on the convex side.

The conch of *Cyrtoceras dictys* Billings is distinctly curved lengthwise and compressed laterally. The species appears related to Specimen 820a, mentioned in the preceding lines, but nothing is known of its siphuncle.

The siphuncle of *Cyrtoceras kirbyi* Whitfield is in contact with the ventral wall of the conch, is 2 mm. in diameter, and its segments appear tubular, constricting slightly along the upper part of the camerae, widening slightly along their lower part, and constricting again where entering the top of the septal neck next beneath. *Cyrtoceras beekmanense* Whitfield appears closely related to *kirbyi*.

In *Cyrtoceras raei* Whitfield, the siphuncle is in contact with the ventral wall of the conch, is 2 mm. in diameter, and its segments appear tubular. Possibly the conch was gyroceran in form, the whorls being depressed dorsoventrally.

In *Cyrtoceras vassarina* Dwight, the conch is laterally com-

pressed, the siphuncle is exogastric, and the vertical outlines of its segments within the camerae are concave.

It is evident that our knowledge of the cyrtoceroids of the Canadian formations is very unsatisfactory. Of course, they would no longer be placed under the genus *Cyrtoceras*, as that genus is restricted at present. *Cyrtoceras metellus* Billings was referred by Hyatt<sup>14</sup> to his genus *Maelonoceras*, but the siphuncle segments of the latter are subfusiform, while those of Specimen No. 820a are strongly nummuloidal.

#### 10. ENDOCERAS HALL

First described species: *Endoceras subcentrale* Hall, from the Black River (Watertown) at Watertown, New York. Pal. New York, vol. 1, 1847, p. 57.

Accepted genotype: *Endoceras proteiforme* Hall. Pal. New York, vol. 1, 1847, p. 208

*Endoceras* belongs to the group of genera in which the septal necks extend posteriorly until in contact with the septum next beneath. It is distinguished from other genera by the presence of long endocones which taper downward gradually to a point. The sides of these endocones are not in contact with the walls of the siphuncle but are free along their entire length. In typical *Endoceras* the endocones are few and distant from each other. Those species in which the endocones are numerous have been placed by Hyatt in his genus *Vaginoceras*.

In distinguishing *Vaginoceras* from *Endoceras*, Hyatt stated<sup>15</sup> that in *Endoceras* the septal necks extend posteriorly from one septum only as far as the septum next beneath, while in *Vaginoceras* the septal necks extend beyond the next lower septum. It would require a monographic study to determine to what extent either the presence of numerous endocones or the long backward extension of the septal necks might be regarded as of generic value. It is still more doubtful if it is possible to distinguish a genus (*Vaginoceras*) in which the septal necks are more than one camera in length, and in which the endocones are numerous, from another genus (*Endoceras*) in which the septal necks are only one camera in length and in which the endocones are relatively few. Apparently, if *Vaginoceras* is to stand, its validity must be based upon one of these criteria alone, and not on both. The one here selected is the presence of numerous endocones, since *Endoceras multitabulatum* Hall is the genotype of *Vaginoceras*.

<sup>14</sup> Hyatt, A., op. cit., p. 280.

<sup>15</sup> Idem, p. 266.

The first species described by Hall under *Endoceras* is *subcentrale* Hall from the Black River (Watertown) at Watertown, New York. The type specimen of this species is numbered 603 in the American Museum of Natural History. The figure presented by Hall<sup>16</sup> shows only the middle half of the specimen and is printed in an inverted position, with the apical end directed upward. Liberties were taken in the preparation of this figure. An endocone is present, as in the figure, but the septal necks appear to extend posteriorly for a distance of two camerae, the lower half of each septal neck invaginating into the upper half of that next beneath. If emphasis be placed on the lack of numerous endocones, then *Endoceras subcentrale* is as typical an example of *Endoceras* as *proteiforme* Hall, the genotype accepted by Bassler.<sup>17</sup> If emphasis be placed on the elongation of the septal necks, then it agrees in this respect with typical *Vaginoceras*. The present writer regards it as an *Endoceras*.

The second and third species described by Hall under *Endoceras*, namely *longissimum* and *multitabulatum*, belong to Hyatt's genus *Vaginoceras*. The fourth species, *gemelliparum*, appears to be a typical *Endoceras*. The fifth species is the genotype of a new genus, *Cyclendoceras*, established by Grabau and Shimer. The sixth species, *proteiforme*, is accepted by Bassler as the genotype of *Endoceras*, since this is the species best known, and represented by the greatest number of specimens.

In describing *Endoceras proteiforme*, Hall discriminated five varieties, namely *tenuistriatum*, *tenuitextum*, *lineolatum*, *strangulatum* and *elongatum*. Of these, *tenuistriatum*, *tenuitextum*, and *lineolatum* are referred by various authors to *Orthoceras*. The variety *strangulatum* is another *Orthoceroid*. Only *elongatum* remains as a probable *Endoceroid*.

Typical *Endoceras proteiforme* Hall is represented by the figures on Plates 48, 49, 50, 53 and 57. The original of Figure 4 on Plate 48 is selected here as the type of the species. The specimens figured on Plate 49 are regarded as cotypes. Owing to the importance of this species in the diagnosis of the genus *Endoceras*, it is described more fully in the following lines.

<sup>16</sup> Hall J., Pal. New York, vol. 1, 1847, pl. 17, fig. 4.

<sup>17</sup> Bassler, R. S., Bibliographic Index of American Ordovician and Silurian fossils; U. S. Nat. Museum Bull. 92, p. 480, 1915.

## 11. ENDOCERAS PROTEIFORME HALL

PLATE XXI, FIGS. 1-3; PLATE XXII, FIGS. 1-3; PLATE XXIII, FIGS. 1-3; PLATE XXV, FIG. 2

*Endoceras proteiforme* Hall, Pal. New York, vol. 1, 1847, pl. 48, fig. 4; pl. 49, 1 a-e

Selected type (Plate XXI, Fig. 1; Plate XXII, Figs. 1A, 1B). The original of Figure 4 on Plate 48 of the publication cited above is selected here as the type of the species. This specimen is 120 mm. long. It enlarges from a diameter of 45 mm. at the lowest well defined camera to 51 mm. at a point 100 mm. farther up, or 6 mm. in a length of 100 mm., indicating an apical angle of  $3^{\circ}$ . The cross-section is approximately circular; possibly there is a little depression dorso-ventrally. The number of camerae in a length equal to the diameter of the conch equals 7 along the entire length of this specimen. The sutures of the septa are directly transverse except along the ventral side of the conch, where they curve more or less distinctly downward on approaching the median part. The septa curve strongly downward, their concavity equaling 9 mm. where the diameter of the specimen is 48 mm. At this point the diameter of the siphuncle is 22 mm. For a width of 10 mm. the siphuncle either is in contact with the ventral wall of the conch or is but very slightly separated from such contact. About 60 mm. farther up, where the diameter of the conch is 52 mm., the diameter of the siphuncle is 30 mm. Immediately above this part of the specimen there is evidence of two endocones, of which the lower one is visible also at the lower point where the diameter of the conch is 48 mm. This lower endocone is estimated to have an apical angle of about  $9^{\circ}$ . It is evident that the two endocones originated at septa separated by an interval of about 7 camerae, or a length equal to the diameter of the conch. Both endosiphococones lie on the dorsal side of the siphuncle, but this varies in different specimens.

Other Specimens Figured by Hall.—The specimen<sup>18</sup> represented by Figure 1a on Plate 49, accompanying the original description by Hall, has the ventral side of the siphuncle exposed along a width of 18 mm.; apparently the exposed part of the siphuncle originally was in contact with the ventral wall of the conch. The septal necks are faintly concave in vertical sections. Apparently they are only a single camera in length, and

<sup>18</sup> Pl. 21, fig. 2; pl. 22, fig. 2; pl. 23, fig. 2, of this Journal.

their basal part curves outward where joining the top of the septal neck immediately beneath. The apical end of an endosiphococone traverses the greater part of the length of this specimen; it is almost in contact with the ventral wall of the siphuncle. The diameter of the siphuncle is estimated at 30 mm. and that of the conch at 58 mm., but in neither case is more than the ventral side actually exposed. Five camerae occur in a length equal to the diameter of the conch. The apical angle appears to be larger than  $3^\circ$ , but the specimen is not suitable for the accurate measurement of this angle.

The specimen<sup>19</sup> represented by Hall's Figures 1b and 1c on Plate 43 exposes 12 camerae in a length of 106 mm. Near the base of the specimen 7 camerae occur in a length equal to the diameter of the conch; near its upper end 6 camerae occur in a corresponding length. At mid-length the diameter of the specimen is 56 mm. Here the concavity of the septa is 15 mm. The diameter of the siphuncle at the top of the specimen is 26 mm. If the siphuncle was not in actual contact with the ventral wall of the conch, it was at least very close to the latter. About 30 mm. below the top of the specimen an endosiphococone starts downward, and 80 mm. farther down its cross-section is seen at a distance of 1 mm. from contact with the dorsal side of the siphuncle. Here its lateral diameter is 15 mm., and its apical angle is approximately  $7^\circ$  or  $8^\circ$ . The apical angle of the conch probably did not exceed  $3^\circ$ .

Figure 1d on Plate 49 of Hall's monograph represents a specimen with more numerous camerae than usual. The upper end of an endosiphococone is exposed.

Figure 1e on plate 49 represents chiefly an endosiphococone<sup>20</sup> with an apical angle of about  $8^\circ$ . It is badly bent at mid-length, and retains there part of the camerate portion of the conch, poorly preserved.

While endosiphococones with apical angles of  $9^\circ$  or  $10^\circ$  are most common, occasional specimens with angles distinctly lower or higher also occur.

Locality and Formation.—Middleville, New York, in the Trenton limestone.

Specimens, with one exception, all numbered 809-1. The originals of fig. 4 on plate 48 and figs. 1a, 1b, 1c, 1e on plate 49 are in the American Museum of Natural History. Fig. 1d on

<sup>19</sup> Pl. 21, fig. 3; pl. 23, fig. 1, of this Journal.

<sup>20</sup> Pl. 22, fig. 3; pl. 23, fig. 3; pl. 25, fig. 2, of this Journal.

plate 49 represents specimen 12082-1 in the State Museum of New York, at Albany.

## 12. CAMEROCERAS CONRAD

Genotype: *Cameroceras trentonense* Conrad. Pal. New York, vol. 1, 1847, p. 221

*Cameroceras* is distinguished from *Endoceras* chiefly by the character of its endocones, which in *Endoceras* are long, gradually tapering, and free from contact with the walls of the siphuncle, except at their extreme top, where, apparently, they are attached to the septal necks forming the siphuncle. The general outline of these endocones is symmetrical in every direction. In *Cameroceras* the conspicuous part of the endocones is short and rapidly tapering. Its straight part is in contact with the ventral wall of the siphuncle, while the oblique part faces toward the interior and is free from contact with the walls of the siphuncle. Immediately above this conspicuous oblique conical part, the endocone contracts more or less, sometimes only to a slight degree. It is not known definitely whether the endocone extends above this slightly contracted part for any considerable distance or not, but apparently it continues in this direction for a length of 6 or more camerae, in cylindrical form. The cylindrical part appears to be a continuation of the downward extension of one of the septal necks. It is not known whether more than one endocone may exist in the same conch. The structure of the endocone apparently is very similar to the "preseptal cone" of *Nanno* and *Suecoceras*, but the conspicuous rapidly tapering part of the endocone is beneath the camerated part of the conch in the latter genera, while it is assumed to be surrounded by the camerated part, some distance above the base of the latter, in *Cameroceras*. This location in *Cameroceras* is indicated, among other things, by the annulation of the rapidly tapering part of the endocone, especially along its free side.

Although a considerable number of endocones are at hand it still remains to determine definitely how much of the overlying cylindrical part of the siphuncular portion of the conch belongs to the endocone, how the endocone is attached to the interior of the siphuncle, and how far above the base of the conch it is attached.

## 13. CAMEROCERAS TRENTONENSE CONRAD

## PLATE XXIV, FIGS. 1-5

*Cameroceras trentonense* Conrad, Jour. Acad. Nat. Sci. Philadelphia, vol. 8, 1842, p. 267, pl. 16, fig. 3; Hall, Pal. New York, vol. 1, 1847, p. 221, pl. 56, figs. 4a-c

Specimens figured by Hall.<sup>21</sup>—Both specimens are compressed laterally, and in each there is a tendency toward angularity on the dorsal or antisiphonal side of the conch. The dorso-ventral diameter of the shorter specimen is 24 mm., and the lateral diameter is 21 mm. Viewed from the ventral side the conch looks slightly broader than when viewed from the dorsal side. The rate of enlargement of the conch evidently was small. The dorso-ventral diameter of the longer specimen is 26 mm. and the lateral diameter is 19 mm. It is possible that this lateral compression is due to pressure during fossilization.

The number of camerae in a length equal to the dorso-ventral diameter of the conch is from three to three and a half. The sutures of the septa curve slightly downward laterally, forming shallow lateral lobes and very low dorsal and ventral saddles; this is another feature which probably is not constant in the species. The septa curve in a dorso-ventral direction with a radius of 14 mm., and laterally with a radius of 8 mm., again suggesting lateral pressure. The siphuncle is in contact with the ventral wall of the conch for a width of 3 or 4 mm., so that this side of the siphuncle does not show the annulations which cross the remainder of the siphuncle obliquely.

In the longer specimen, the conch is straight; the exposed part of the siphuncle is likewise straight; the bend at the junction of the siphuncle with a remainder of the conch evidently is due to distortion during fossilization. In the shorter specimen, the septal necks contract within the upper half of the camerae, expand within the lower half, and then contract again toward their lower margin, so as to admit of the insertion of this margin into the top of the next lower septal neck. The surface of the conch apparently is smooth.

*Locality and Horizon.*—Middleville, New York; in the Trenton limestone.

Specimens No. 815, American Museum of Natural History.

*Multona Brook and Poland* specimens.—Cross-section of conch

<sup>21</sup> This Journal, pl. 24, figs. 1, 2.

nearly circular, slightly depressed. In one specimen, (fig. 4), the dorso-ventral diameter equals 22 mm. and the lateral diameter 23 mm., the diameter of the siphuncle being 11 mm. The number of camerae in a length equal to the diameter of the conch is 4. The sutures of the septa are directly transverse, curving downward slightly along the median part of the ventral side and sometimes also laterally. As far as known, the septal necks extend downward the length of one camera, and invaginate into the top of the septal neck next beneath.

In the second of the specimens from Multona brook (Pl. 24, Fig. 3), the siphuncle is in contact with the ventral wall of the conch, and is flattened and not annulated along this line of contact. Around the remainder of its circumference the siphuncle is strongly annulated, in an oblique direction, the annulations forming an angle of  $70^\circ$  with the vertical axis of the conch. Toward the tip of the endocone the angle made by the annulations appears to become a little more acute.

The interior of the rapidly contracting part of the endocone and the adjacent part of the cylindrical siphuncle, immediately above, is lined by a calcareous deposit. In the Poland specimen (Pl. 24, Fig. 5), this calcareous deposit fills the lower part of the endocone for a distance of 7 mm. from its tip. Immediately above this level the thickness of the calcareous deposit equals 2 mm. At the upper end of the inversely conical part of the endocone, the thickness of the calcareous deposit is 1 to 1.5 mm. Four camerae farther up, within the cylindrical part of the endocone, the thickness of the calcareous deposit is reduced to half a millimeter.

Two of the specimens from Multona brook preserve casts of the interior of the endocone; one of these is figured here (Pl. 24, Fig. 3). It has proved impossible so far to determine with confidence how much of the conch is to be included in the structure here called the endocone. The conspicuous part of the endocone, which tapers rapidly downward, varies from 4 to 6 camerae in length in different specimens, but it is not known how much of the overlying cylindrical part is to be included in the endocone. In other words, it has been impossible, so far, to distinguish between the walls of the siphuncle and the walls of the endocone, or to determine at what level the top of the cylindrical portion of the endocone originates. Possibly all of the cylindrical portion

belongs to the siphuncle, and no part of this cylindrical portion to the endocone.

*Locality and Horizon.*—Multona brook, 2 miles northeast of Middleville, New York; specimens No. 59449, U. S. National Museum. One mile above Poland, in Herkimer county, New York; specimen 59450, U. S. National Museum. Both localities in the Trenton limestone.

14. CAMEROCERAS CALUMETTENSE SP. NOV.

PLATE XXIV FIGS. 6A-E

Specimen 65 mm. in length, consisting of part of a siphuncle traversing nine camerae in a length of 52 mm. and terminating at the base in an endocone three camerae in length. Possibly the siphuncle is one camera less and the endocone one camera more in length, since in two other specimens the endocone is four camerae in length.

In the longer specimen here figured (Pl. XXIV, Figs. 6A, B), the siphuncle narrows from a width of 12 mm. immediately above the point of departure of the endocone to 10.5 mm., 8 camerae farther up. A second specimen shows the same narrowing of the siphuncle in an upward direction.

Not only the siphuncle, but also the endocone, is flattened ventrally by contact with the ventral wall of the conch. This is indicated by 3 specimens. (Plate XXIV, Figs. 6A, C). Except along this flattened ventral part, both the siphuncle and the endocone are annulated toward the interior of the conch. The lower margin of the septal funnels, as seen on casts of the interior of the siphuncle, forms an angle of  $60^{\circ}$  to  $70^{\circ}$  with the vertical axis. Along the greater part of its length, the annulations of the siphuncle are parallel to the lines of contact with the septa, but, on approaching the upper margin of the endocone from above, the angle made by the annulations changes to  $75^{\circ}$  or  $80^{\circ}$  with the vertical, thus shortening the distances between the annulations on the dorsal side of the siphuncle.

On the ventro-lateral sides of the siphuncle, vertical sections of the septa can be traced for 6 mm. from the siphuncle. Ventrally, the siphuncle was in direct contact with the wall of the conch.

The siphuncle appears to consist of a darker exterior layer and a lighter colored interior one. The darker layer evidently is a continuation of the septum and can be traced downward the

length of one camera where its margin invaginates into the upper part of the septal neck next beneath. The lower margin of each septal neck extends about 1 mm. below the top of the underlying one. The light colored layer appears to be merely a calcareous inner lining of the darker colored one and, as far as known, also extends downward only the length of a single camera.

The interior of both the siphuncle and of the endocone (Plate XXIV, Figs. 6D, E), is lined by a calcareous deposit, which attains a thickness of about 4 mm. at the top of the endocone, diminishing to 2 mm. about 3 camerae farther up, and to about three-quarters of a millimeter 8 camerae above the top of the endocone. About half way down the length of the endocone the calcareous deposit completely fills its interior. The matrix filling the upper half of the axial part of the endocone and the overlying part of the siphuncle is obliquely annulated in a manner strictly corresponding to the annulations on the exterior of the siphuncle, but the annulations are less prominent. Passing along the axial part of the solid deposit filling the lower half of the endocone is a thin band, a millimeter or less in width, but only about one-fifth of a millimeter thick dorso-ventrally, which evidently was originally an endosiphuncle, filled in successively from above by curved transverse, thin layers whose concave sides face upward.

*Locality and formation.*—From the cephalopod bed at the base of the Maquoketa on Little Calumet creek, 6 miles south of Louisiana, Missouri. Collected by Ulrich and Kirk in 1911, and now in the U. S. National Museum.

#### 15. ASCOCERAS BARRANDE

Genotype: *Ascoceras bohemicum* Barrande. Barrande, Syst. Sil. du Centre Boheme, pl. 93

The Silurian genera *Ascoceras*, *Glossoceras*, and *Aphragmites* have laterally compressed gerontic living chambers, differing in this respect from the Ordovician genus *Billingsites* in which these chambers are depressed dorso-ventrally. In the three Silurian genera the upper part of the living chamber is contracted into a tubular portion which terminates in *Ascoceras* and *Aphragmites* in a simple transverse aperture, but which in *Glossoceras* has distinct dorsal and lateral crests, with intermediate sinuses. The general transverse section of the upper tubular portion may be circular or moderately depressed dorso-ventrally. In *Ascoceras*

and *Glossoceras* the exterior of the shell is smooth. In *Aphragmites* the exterior of the living chamber is sharply annulated transversely.

In American strata the genus *Ascoceras* is represented by the species *Ascoceras indianense* Newell from the Niagaran at Delphi, Indiana, *Ascoceras southwelli* Worthen from the Niagaran at Port Byron, Illinois, and *Ascoceras townsendi* Whiteaves from the Niagaran (Guelph) at Durham, Ontario. In the last named species the gerontic group of living chambers appears to have been relatively much shorter than in typical forms of *Ascoceras*.

#### 16. BILLINGSITES HYATT

Genotype: *Ascoceras canadense* Billings. Rep. Progress for 1853-56, 1857, Geol. Surv. Canada, p. 310; Geol. Canada, 1863, p. 318, fig. 227

*Billingsites* differs from typical *Ascoceras* chiefly in having the gerontic group of living chambers dorso-ventrally depressed, instead of laterally compressed as in the latter genus. The contracted part of the living chamber, above the level of the uppermost dorsal saddle, is much shorter in *Billingsites* and is more distinctly depressed dorso-ventrally. The margin of the aperture is transverse, without crests or sinuses. The genus is known so far only from the Ordovician.

The genus *Billingsites* includes *Billingsites anticostiensis* (Billings) from the Gamachian (Ellis Bay) of Gamache Bay, Anticosti; *Billingsites borealis* (Parks) from the Richmond (Shammattawa) of Shammattawa river, Manitoba; *Billingsites costulatus* (Whiteaves) from the Richmond of the Lake Winnipeg region in Canada; and *Billingsites newberryi* (Billings) from the Richmond (English Head and Vaurial) and Gamachian of English Head and other localities on Anticosti. The genotype is *Billingsites canadensis* (Billings) from the English Head and Vaurial of Anticosti.

The specimen described by Sardeson under the name *Ascoceras gibberosum*, from the Ozarkian (Oneota) of Dresbach, Minnesota, according to Dr. E. O. Ulrich belongs to a new genus of *Chiton*, related to *Priscochiton*, now under investigation.

#### 17. BILLINGSITES (?) WILLIAMSPORTENSIS SP. NOV.

PLATE XXXV, FIGS. 2A, B, C

The specimen has the external form of the gerontic living chamber of a *Billingsites*. It is depressed dorsoventrally, and the more convex side is regarded as ventral, the less convex as

dorsal. A vertical dorsoventral section through the center of the specimen exposes two septa, of which the lower is more distinct. This septum rises from a level of 6 mm. above the base of the specimen on its ventral side to 17 mm. at a point 4.5 mm. distant from its dorsal wall. The upper septum is 4 mm. above the first on its ventral side and rises to 25 mm. above the base of the specimen at a point 1.5 mm. from its dorsal wall. The dorsal terminations of these septa are unknown; no trace of the siphuncle remains.

The lateral view reproduced as figure 2A, Plate XXXV, shows the ventral side on the left. Figure 2B on the same plate presents the ventral side, and figure 2C the dorsal.

Locality: From the Catheys formation at Williamsport, Tennessee. Specimen 48395 in the U. S. National Museum.

Remarks: This species may be a precursor of typical *Billingites*, the rise of the septa on its dorsal side forshadowing the formation of the strongly developed dorsal saddles of that genus.

#### 18. ORTHOCERAS BREYNIUS

The name *Orthoceras* or *Orthoceratites* was applied first by Breynius<sup>22</sup> to erratic specimens found in the vicinity of Danzig in Germany. From this location it may be assumed that the erratic blocks containing these specimens were either of Ordovician or Silurian origin. There is a possibility that some one visiting the original locality might be able to identify the species figured. Nothing is known as to the fate of the original specimens.

The figures published by Breynius show that the rate of enlargement of the species described by him was very small. The septa were relatively distant, about 2 camerae occurring in a length equal to the diameter of the conch. The siphuncle was small, somewhere between one-sixth and one-seventh of the diameter of the conch. Its segments were cylindrical, not enlarging within the camerae. The septa were deeply concave.

The nearest approach to *Orthoceras*, as figured by Breynius, with which the writer is familiar, is a species of *Lituites*, from Esthonia, well represented in the collection of the U. S. National Museum (Plate XXVIII, Fig. 3). In these specimens the annulations on the exterior of the shell are accompanied by very weak annulations on casts of the interior. The camerae of this

<sup>22</sup> Dissert. Phys. de Polythalmiis, 1732, pp. 12, 19, 31; Pl. III, Figs. 1-7.

species are relatively long, and the siphuncle is only moderately excentric.

It is evident that the type of *Orthoceras*, if this genus is to be accredited to Breynius, must be some species which could have been carried southward by glacial action to the vicinity of Danzig. If any true Orthoceroid is known which could have been the species figured by Breynius, it is desirable that attention be called to this fact.

In this connection it might be of interest to note that the genus *Lituities* was defined by Breynius in the same work in which he defined *Orthoceras*. In neither case was a binomial nomenclature used, and it is doubtful whether either genus, under these circumstances, should be ascribed to Breynius.

The species figured by Breynius is cited by Schlotheim in his description of *Orthoceras regulare*, evidently in the belief that the two were identical.

However, it is evident from his citations of figures of orthoceracones published by Bosc, Knorr, and Breynius, that he included several species under this name, and that the species figured by Breynius can not be considered the type of *regulare*.

Hyatt restricted the term *Orthoceras* to forms with smooth shell, and stated<sup>23</sup> that he had met but two species in North America, though doubtless others may exist. In the Zittel-Eastman Text-book of Paleontology he figured two species under *Orthoceras*, namely *intermedium* Marklin from the Silurian of Gotland, and *melchlini* Barrande from the Silurian of Bohemia. Of these two species, the first differs from typical *Orthoceras* in the greater number of its camerae (about 8 in a length equal to the diameter of the conch), and in the distinct, though slight, enlargement of the siphuncle within the camerae. The second species, however, is closely similar to typical *Orthoceras* in the elongation of its camerae and in the tubular form of the segments of its siphuncle. Until the exact status of the species figured by Breynius can be determined, *Orthoceras melchlini* Barrande may be accepted as the type of *Orthoceras* as restricted by Hyatt.

Typical *Orthoceras* occurs chiefly in the Silurian, but similar specimens apparently occur also in the Richmond formation, in the upper part of the Ordovician. A description of the species occurring in the Richmond at Clarksville, Ohio, follows:

<sup>23</sup> Hyatt, A., Genera of fossil cephalopods; Proc. Boston Soc. Nat. Hist., vol. 22, p. 275, 1883.

## 19. ORTHOCERAS CLARKSVILLENSE SP. NOV.

## PLATE XLII

Specimen 130 mm. in length, consisting of 16 camerae, of which the uppermost is distinctly shorter, suggesting that the conch had reached full maturity. The specimen apparently enlarges from a diameter of 21 mm. at its base to 28 mm. at its top, indicating an apical angle of about  $4^{\circ}$ . Near the base of the specimen two and a half camerae occur in a length equal to the diameter of the conch. Toward the upper part, three camerae occur in a corresponding distance. The sutures are directly transverse. The septa have a concavity of 5 or 6 mm. at mid-length of the specimen. The center of the siphuncle is located about one-third of the diameter of the conch from its central side. The segments of the siphuncle are cylindrical in form and their diameter is about 3 mm. along the entire length of the specimen. No part of the exterior shell remains, but the cast of the interior of the conch is smooth and it is possible that the exterior of the shell was smooth also.

*Locality and Horizon.*—Clarksville, Ohio; either from the Liberty or the Waynesville member of the Richmond.

Specimen No. 48255, in the U. S. National Museum.

Similar specimens have been collected by Prof. W. H. Shideler in the basal part of the Liberty at Clarksville, Ohio; and in the lower Whitewater, on Dodge creek, near Oxford, Ohio.

A similar specimen, but with somewhat more distant septae, was found in the Richmond about a mile north of the light house at the southern end of Bay de Noc peninsula, in Northern Michigan, in strata probably equivalent to the Whitewater member.<sup>24</sup> Additional specimens have been found in the Stonington area, farther northward on the same peninsula, by Dr. R. C. Hussey, of the University of Michigan.

Remarks.—It has not been determined to what extent the form of the segments of the siphuncle in Orthoceroids is dependent on the relative distance between the septa. In general it may be stated that in those forms in which the septa are more distant from each other the segments of the siphuncle tend to expand less within the camerae, sometimes being cylindrical, while

<sup>24</sup> Foerste, A., The Richmond faunas of Little Bay de Noquette in northern Michigan; Ottawa Nat., vol. 31, p. 122, pl. 5, fig. 19, 1917.

in forms in which the septa are relatively close together these segments tend to be globular or nummuloidal.

Cylindrical segments are frequent in such genera as *Dawsonoceras*, *Kionoceras*, and *Protokionoceras*; they occur also in some species of *Spyroceras* and *Cycloceras*. Evidently, the cylindrical form of the segments of the siphuncle is not sufficient, in itself, to determine the generic relationship of an Orthoceroid cephalopod. According to the Hyatt classification, the character of the surface ornamentation also must be taken into account.

## 20. GEISONOCERAS HYATT

Genotype: *Orthoceras rivale* Barrande; Syst. Sil. du Centre Boheme, pl. 209

The genus *Geisonoceras* was erected by Hyatt for the banded Orthoceroids of Barrande. A banded form differs from a transversely striated one in having the striae more distant, the upper margin of the band being abruptly defined, while the general surface of the band contracts gently and evenly in an apical direction. Successive bands overlap each other in an oral direction. The genus probably was evolved from forms having relatively closer transverse striae. According to Hyatt, the young are either smooth or transversely striated.

Hyatt selected as the type of this genus *Orthoceras rivale* Barrande, from the Silurian of Bohemia. In this species two and a half camerae occur in a length equal to the diameter of the conch. The siphuncle is slightly excentric, and it enlarges slightly within the camerae. In the Zittel-Eastman Text-book of Paleontology he figures as *Geisonoceras* the *Orthoceras timidum* Barrande of the Silurian of Bohemia, and defines the genus without referring to its characteristic transverse banding. The genus *Geisonoceras*, however, must be regarded as founded upon *Orthoceras rivale*, the original type, and not on *Orthoceras timidum*.

In the Zittel-Eastman textbook, Hyatt defines *Orthoceras* as having a siphuncle centren or slightly dorsad of the center. The siphuncle of *Geisonoceras* is stated to be centren or slightly ventrad of the center. As applied to Orthoceroids, the terms dorsad and ventrad need some explanation. In those specimens in which the conch is distinctly though slightly curved lengthwise, the convex side usually is regarded as the ventral one. Theoretically, the ventral side should be located by the presence of an hypo-

nostic sinus. However, since Orthoceroids do not have an hyponomic sinus, this method of orienting the conch can not be used for them. When the transverse striae slope distinctly downward from one side of the conch to the other, the lower part of their course is supposed to correspond to the hyponomic sinus, at least in those forms which are not curved lengthwise. It may be acknowledged freely that in the present state of our knowledge of the Orthoceroids the terms dorsal and ventral are used loosely. In the absence of all other criteria, that side of the conch which is nearest the siphuncle is called the ventral one, at least provisionally.

Banding is by no means confined to the genus *Geisonoceras*. It occurs also in breviconic forms, as indicated by Hyatt,<sup>25</sup> and in some species of Actinoceroids.

#### 21. CYCLOCERAS McCoy

The genus *Cycloceras* was defined by McCoy<sup>26</sup> as consisting of "those conical species marked with prominent concentric rings, and having the surface frequently sculptured with transverse scaly laminae, and often decussated; siphuncle dorsal." This description is accompanied by a small figure with vertical striae or ribs, but the figure does not resemble any species described or listed by him in the text. Among the species known at that time, it most resembles *Orthoceras rugosum* Fleming, as represented by Phillips,<sup>27</sup> and that species is therefore regarded here as the genotype. In this figure the annulations are tuberculated by longitudinal echinated lines, of which there are apparently about 18 on the entire circumference of the conch. The expression, "siphuncle dorsal," at present would be changed to siphuncle ventral.

None of the species described or listed by McCoy in the body of his text agrees with his description of the genus in the possession of vertical lines of any kind. The first species mentioned was originally described by Fleming<sup>28</sup> as *Orthocera annularis*. Fleming's illustration is reproduced herewith as figure 4, plate XXV. The surface of this species is said to be smooth, except

<sup>25</sup> Hyatt, A., op. cit., p. 275.

<sup>26</sup> Syn. Carb. Foss. Ireland, 1844, p. 6, fig. 6.

<sup>27</sup> Geology of Yorkshire, 1836, pl. 21, fig. 16. See also Fleming, Ann. Phil. vol. 5, 1815, p. 203, pl. XXXI, fig. 9.

<sup>28</sup> Ann. Phil., vol. 5, 1815, p. 203, pl. 31, fig. 8.

for the annulations. A larger form was given the same name by Phillips<sup>29</sup> and his illustration is here reproduced as figure 5, plate XXV. Its surface had annular ridges and intervening waved striae. The second species described by McCoy is *Cycloceras laevigatum* McCoy, represented by him as figure 3 on his plate 1. At the time of the original description no transverse striae were known. Probably the type was a cast of the interior of the conch, on which the surface striae leave no impress. Later Foord<sup>30</sup> figured specimens of the same species in which transverse striae are present where the shell is preserved. His illustrations are reproduced herewith as figures 3A and 3B on plate XXVII. Possibly the surface of the shell of *Orthoceras annularis* Fleming was similarly striated.

The third species described by McCoy under *Cycloceras* was the form described by Phillips<sup>31</sup>, in the body of his text, as *Orthoceras annulatum*, but which in his description of plates he referred to *Orthoceras annulare*. This form possesses transverse striae in addition to the annulations, but there are no vertical striae or ribs. It is the only one of the three forms listed by McCoy in which transverse striae were known to be present at the time of the description of his genus *Cycloceras*. McCoy identifies this species with *Orthoceras lineolatum* Phillips and cites the description based on the specimen represented in this Journal on pl. XXV, (fig. 5).

It appears, therefore, that McCoy included in his genus *Cycloceras* at least two distinct types of structure. In one, the annulations were tuberculated where crossed by longitudinal lines; in the other only transverse striae were present in addition to the annulations. The first type of structure is that indicated by his original description and the accompanying small figure. The second type of structure is that of the three species mentioned by McCoy in the body of his text.

Hyatt<sup>32</sup> in 1883 defined *Cycloceras* as including transversely striated Palaeozoic longicones, which at some stage of their growth have annular costae. Subsequently in the Zittel-Eastman Text-book of Paleontology, he re-defined the genus as including annulated orthoceracones and cyrtoceracones with discontinuous

<sup>29</sup> Geology of Yorkshire, 1836, pl. 21, fig. 9.

<sup>30</sup> Carb. Ceph. Ireland, 1897, pl. 5, fig. 1.

<sup>31</sup> op. cit., p. 239, pl. 21, figs. 9, 10.

<sup>32</sup> Hyatt, A., op. cit., p. 275.

longitudinal ridges. The first of these definitions evidently is based on the species cited in McCoy's text. The second definition is based on the original description of the genus and the small accompanying figure. Accepting the latter as the more correct interpretation of the genus, the forms possessing only transverse striae and no longitudinal markings, have no distinct generic designation, and the term *Perigrammoceras* here is proposed.

Bassler lists under *Cycloceras* a number of species having vertical striae or ribs in addition to annulations. These include *Orthoceras crocus* Billings, *O. olorus* Hall, *O. olorus baffinense* Schuchert, *O. perroti* Clarke, and *O. teretiforme* Hall. It is not known definitely whether *Orthoceras leseuri* Clarke, *O. nicolleti* Clarke, and *O. rectiannulatum* Hall belong to the same group as the preceding list, since the finer surface structure of these species is not known, only the presence of annulations being certain. It is probable that these Ordovician forms are distinct generically from typical *Cycloceras*, as found in Carboniferous strata. Provisionally they are associated with *Spyroceras*.

*Orthoceras inceptum* Foerste and its variety *acceleratum* Foerste apparently belong to *Orthoceras*, as far as known.

*Orthoceras (Cycloceras) novacarlistense* Foerste has sharply defined transverse striae, but no annulations. Evidently it does not belong to *Cycloceras*. Its nearest relationship probably is with *Geisonoceras*.

The transverse striae of *Orthoceras amycus* Hall, are gently frilled, and the species belong to *Dawsonoceras*.

## 22. PERIGRAMMOCERAS GEN. NOV.

PLATE XXVII, FIGS. 3 A, B.

Genotype: *Orthoceras laevigatum*, as figured by Foord, in Carb. Ceph. Ireland, 1897, pl. 5, figs. 1d, 1e

Orthoceracones with transverse annulations and striae, but without vertical striae or ribs. Carboniferous.

It is not known definitely whether this genus is represented in earlier strata or not. In annulated forms with transverse striae occurring in the Ordovician and Silurian it usually is possible to detect also vertical striae or ribs, if the surface is sufficiently well preserved.

## 23. DAWSONOCERAS HYATT

Genotype: *Orthoceras annulatum* of McGill college, Montreal

*Dawsonoceras* is another instance of a genus erected by Hyatt chiefly with Barande species in mind, but with an American species designated as the type. In his original description he states that the genus includes forms like *Orthoceras pseudocalamiteum* Barrande, but at the close of his description he designates *Orthoceras annulatum*, from the Museum at McGill College, as the type. The latter belongs to the species characterized by transverse annulations and transverse frilled striae. Longitudinal ridges, considerably less conspicuous than the transverse annulations, may or may not be present.

In the Zittel-Eastman Text-book of Paleontology Hyatt figures under *Dawsonoceras* the *Orthoceras annulatum* of Bohemia, after Barrande, and not the specimen in the Museum of McGill College. It is evident, from the presence of frilled transverse striae, that *Orthoceras amycus* Hall belongs in the genus *Dawsonoceras*.

In *Perigrammoceras* the transverse striae are straight and not frilled.

## 24. SPYROCERAS HYATT

Genotype: *Orthoceras crotalum* Hall. Pal. New York, vol. 5, pt. 2, 1879, pls. 42, 82, 113

In defining this genus Hyatt apparently had in mind chiefly groups 5 and 6 of the species of *Orthoceras* described by Barrande, but, when it came to selecting the genotype, he chose *Orthoceras crotalum* Hall from the Hamilton formation of New York.

The conch of *Orthoceras crotalum* is crossed transversely by strong, sharply defined, and rather distant annulations. The vertical striae are very fine and closely crowded. A similar species, with closely crowded vertical striae, but with wider and less sharply elevated annulations, is found in the Richmond of Anticosti.

In general, however, the earlier species of *Spyroceras*, in the Ordovician, have stronger and less crowded vertical markings, often designated as ribs, or as ribs alternating with vertical striae. These may form a group distinct from the finely striated forms.

## 25. LOXOCERAS McCoy

## PLATE XXVIII, FIGS. 2A, B

Selected genotype: *Loxoceras distans* McCoy

The genus *Loxoceras* was defined by McCoy as consisting of orthoceracones "in which the section is oval, the septa waved and placed obliquely with respect to the axis of the shell, and the siphuncle is excentric." This description is accompanied by a figure,<sup>33</sup> in which the sinuosity of the sutures of the septa agrees with that of *Loxoceras distans* McCoy, though the septa are drawn closer together. A study of the figures presented by McCoy in connection with his generic descriptions, in the volume cited, suggests that these figures were intended to be diagrammatic, and not accurate representations of type specimens. Moreover, he certainly never intended the first species described in the text under this generic name to be accepted as the type. Had he done so, he would not have published *Orthoceras breynii* Martin (Plate XXV, Fig. 3) first, but would have selected the one he published second, namely *Loxoceras distans* McCoy, which differs from the figure accompanying the original description of the genus chiefly in having more distant septa. The sutures of *Orthoceras breynii* present undulations, but of moderate obliquity compared with typical *Loxoceras*, and the siphuncle is located near the middle of that broad side of the conch along which the sutures curve moderately downward.

In *Loxoceras distans*, on the contrary, the sutures of the septa are strongly oblique in a sigmoid direction, and the location of the siphuncle is central. The word *Loxoceras* means oblique horn, and evidently refers to the strongly oblique sutures.

The siphuncle of *Orthoceras breynii* Martin is described by McCoy as follows:

"Siphuncle small, and a little within the margin, where it passes through the septa, but dilated between them into depressed spheroidal beads, about twice as wide as long, and touching the surface throughout the length of the shell; interior of the siphon traversed by a small continuous tube, attached to the inner walls of the dilated portion by radiating, vertical, shelly partitions (about eight in a whorl), constricted by transverse stronger partitions in the middle of each dilation (or intermediate between the septa). Surface, (of the shell) indistinct, apparently marked with fine, obtuse, transverse striae. The proportion of

<sup>33</sup> McCoy, Syn. Carb. Foss. Ireland, 1844, p. 6, fig. 3.

the long and short diameter of the section is as 100 to 85. A specimen five inches long is one inch three lines wide at the large end, and two lines wide at the apex, the dilated part of the siphon at the latter point equalling the whole diameter of the shell, but being only 5 lines wide at the anterior (upper) end, where two chambers occupy a space of slightly less than half an inch, while six chambers occupy the same space at the smaller end. The internal structure is that of *Actinoceras* Stokes, though it is marginal in position, and the septa are more oblique."

McCoy evidently had not a very clear idea as to the limits of his genus *Loxoceras*. This is shown by the fact that the species described third under *Loxoceras*, namely *Loxoceras incomitatum* McCoy, does not have the strongly oblique sutures. His fourth species was *Orthoceras laterale* Philips. The longitudinal view presented in Figure 3 accompanying the original description of the genus is regarded here as a diagrammatic representation of his species *Loxoceras distans*, while the small cross-section is intended to show the course of the sutures in *Orthoceras breynii*, the siphuncle of the latter being located along the middle of that broad side along the median line of which the sutures curve moderately downward.

## 26. SACTOCERAS HYATT

Genotype: *Orthoceras richteri* Barrande. Syst. Sil. du Centre Boheme, pls. 318, 349

Orthoceracones with relatively small siphuncles, the segments of the latter nearly spherical or slightly elongated. Septal necks short, enveloped on the interior of the siphuncle by lunate calcareous deposits, which enlarge as in other *Actinoceroids*. Sutures of the septa directly transverse. Described from the Silurian.

It is doubtful whether the Carboniferous species *Loxoceras distans* is to be regarded as congeneric with *Sactoceras*. Using the former as the type of *Loxoceras*, there appears to be use for *Sactoceras* as the designation of a distinct group, certainly present in the Silurian, and apparently beginning with forms in the Ordovician in which calcareous deposits of an *Actinoceroid* nature are unknown.

27. **ELRODOCERAS GEN. NOV.**Genotype: *Cryptoceras indianense* Miller

Conch Actinoceroid, cyrtoceraconic at the base, relatively straight at later stages of growth. Siphuncle ventrad of the center of the conch. Segments of the siphuncle presenting moderately convex vertical outlines; general form barrel-shaped, the end flat, and in contact with the intervening part of the septa. Surface of the conch transversely striated or banded as in the banded orthoceracones included by Hyatt under *Geisonoceras*. The bands curve downward along the ventral side of the conch, indicating a shallow but distinct hyponomic sinus.

*Rhynchorthoceras* Remele belongs to the Lituitidae, a family confined to the Ordovician.

The name *Elrodocras* is proposed in honor of Dr. Moses N. Elrod, an indefatigable collector long living at Hartsville, Indiana.

28. **ELRODOCERAS INDIANENSE (MILLER)**

PLATE XXXV, FIGS. 1A, B; PLATE XXXVI, FIGS. 1A, B; PLATE XXXVII, FIGS. 2, 3; PLATE XXXVIII, FIGS. 2, 3

*Cryptoceras indianense* Miller; 17th Ann. Rep. Dep. Geol. Nat. Res.

Indiana, 1892 p. 698, pl. 18, figs. 1, 2

*Rhynchorthoceras dubium* Hyatt; Proc. Amer. Phil. Soc., vol. 32, 1894, p. 512

*St. Paul type*.—Early stages cyrtoceraconic, later stages relatively straight. The lengthwise convex curvature along the lower end of the ventral side has a radius of about 40 mm., the corresponding concave curvature of the dorsal side being much less. The specimen includes 15 camerae, in addition to which a trace of a segment of the siphuncle is seen at its base. Along the upper 9 or 10 camerae the ventral side of the conch is straight lengthwise. The sutures of the septa are directly transverse to the conch. The siphuncle is well exposed within the upper 4 camerae. Within the uppermost camera, its maximum diameter is 23 mm., narrowing to 19 mm. at the septa. The septa wedge in between the successive barrel-shaped segments, the central passage through the septa being 12 mm. in diameter. At the septa, the siphuncle is 12 mm. distant from the ventral wall of the conch, and about 23 mm. from its dorsal wall, the entire diameter being estimated at 54 mm.

The uppermost segment of the siphuncle exposes a cast of its interior; the latter is marked vertically, both above and below an irregular transverse line which crosses the cast not far above

mid-height. This transverse line indicates where the calcareous deposits enveloping the successive septal necks of the siphuncle meet, as in other Actinoceroids. At the top of the specimen, the interior of the siphuncle shows an irregular central depression, probably corresponding to the so-called endosiphuncle of Actinoceroids.

The interior of the camerae is occupied by a calcareous deposit, showing a few cystoid markings, and also a tendency toward pseudo-septa.

The exterior surface of the shell is striated transversely by narrow bands, abruptly limited along their upper margins, but more gradually sloping toward their lower margins. About 14 to 16 transverse striae occur within a length of 10 mm. On the dorsal and lateral sides of the conch these striae are directly transverse, but along the ventral side they curve gently downward.

*Locality and Horizon.*—St. Paul, Indiana, in the Laurel limestone (Silurian).

Specimen No. 633, in the Indiana State Museum, at Indianapolis, Indiana.

*Hartsville type.*—The second specimen figured by Miller, in his original description of *Cyrtoceras indianense*, consists of 11 camerae. The lengthwise convex curvature of the ventral side along the 3 lower camerae has a radius of 45 mm.; the fourth camera is distinctly less curved, and the ventral side of the upper part of the conch is straight. In a corresponding manner, the dorsal side of the specimen is concavely curved along the 3 or 4 lower camerae, and becomes straight farther up. The dorso-ventral diameter enlarges from 29 mm., at the top of the third camera from the base, to 36 mm. at the top of the seventh camera, the intervening distance being 45 mm. This suggests an apical angle of  $9^{\circ}$  along the straight part of the specimen. The specimen is curved laterally, especially along the lower part.

There are three camerae in a length equal to the dorso-ventral diameter of the conch at mid-length of the specimen. The upper four segments of the siphuncle are exposed. Their height is 11 mm. They are represented by deposits lining the interior of their walls. From these deposits it is evident that the diameter of the segments enlarges scarcely 2 mm. on passing from their contact with the septa to their greatest diameter at mid-height. Where the dorso-ventral diameter of the conch is 36 mm., the

maximum diameter of the segments of the siphuncle is 13 mm. At its passage through the center of the septum the siphuncle is constricted abruptly to a diameter of 5 or 6 mm. The outer surface of the deposit which lines the inner side of the walls of the segments of the siphuncle is corrugated vertically. A short distance above mid-height of the segments, these corrugations are interrupted by a horizontal groove. This groove marks the line at which deposits embracing successive septal necks meet.

The thickness of the shell is somewhere between one-half and three-quarters of a millimeter. Its outer surface is striated or banded transversely. Along the lateral sides of the conch these striae are directly transverse, but along its ventral side they curve downward moderately, locating the hyponomic sinus.

*Locality and Horizon.*—From Hartsville, Indiana, at the top of the Laurel limestone, immediately beneath the Waldron shale.

Specimen No. 6056, In the Walker Museum at Chicago University.

*Rhynchorthoceras dubium.*—The type of *Rhynchorthoceras dubium* is curved at its base, but straight farther up. One of the lateral sides retains the surface striae, curving downward ventrally. The opposite lateral side exposes the sutures of the septa. The conch is slightly compressed laterally, and the siphuncle is located ventrad of the center of the conch. A second specimen, not described by Hyatt, shows very well the downward curvature of the transverse striae along the ventral side of the conch. The opposite side exposes the sutures of the septa, which are directly transverse. The siphuncle is seen at the top of the specimen. (Plate XXXV, Figs. 1A, B.)

*Locality and Horizon.*—Hyatt referred to his type as occurring in the Niagara group of Indiana. The exact locality is unknown, but it probably came from the upper part of the Laurel limestone in the St. Paul or Hartsville area. This type is numbered 2132 in the Museum of Comparative Zoology at Harvard University. The second specimen is numbered 2133.

*Joliet specimen.*—One specimen includes, at its base, part of the lengthwise curved portion. The transverse striae curve distinctly downward on the ventral side of the conch. There is a tendency toward obscure transverse costae, which slope obliquely downward from the dorsal toward the ventral side of the conch at a rate much more rapid than that of the transverse striae.

One of the segments of the siphuncle, at the base of the specimen, exposes the deposit lining the interior of the siphuncle, and the abrupt constriction of the siphuncle where it passes through the septum. Specimen No. 22920, in Walker Museum at Chicago University. A fragment of a siphuncle, showing the abrupt constriction of the siphuncle, is referred to the same species. It (Plate XXXVIII, Fig. 3) is numbered 22916 in the same museum. Both are from the Niagaran.

*Lemont specimen*.—A specimen (Plate XXXVII, Fig. 3) exposing the structure of the interior of the conch, from the Niagaran at Lemont, Illinois, is numbered 22917 in Walker Museum.

#### 29. TRIPTEROCERAS HYATT

Genotype: *Orthoceras hastatum* Billings. Geol. Surv. Canada, Rep. Progress for 1853-56, published in 1857, p. 333

Original Description: *Tripteroceras* has similar forms and sutures to *Eudoceras*, but the lateral saddles are acute. The venter is flattened, and broader than the dorsum, which forms the apex of the subtriangular section. The siphon is ventral and nummuloidal, and the whorl arcuate in the young, though straight in the full grown, and the aspect altogether distinct from the shells of *Eudoceras*. The young are similar to the adults of *Eudoceras*.<sup>34</sup>

The genotype is *Orthoceras hastatum* Billings. An examination of the types in the Victoria Memorial Museum at Ottawa, Canada, shows that these types include two species, one of which is described here as *Tripteroceras pauquettense*.

The siphuncle of *Orthoceras hastatum* was described by Billings as small, close to the centre of the ventral margin. The absence of any further description of the siphuncle suggests that, at the time the original description of this species was being prepared, the specimen here called *Tripteroceras pauquettense* did not form part of the type series of *Orthoceras hastatum*, but was added subsequently. The siphuncle of typical *Orthoceras hastatum* appears to be narrow, and not nummuloidal. Omitting this one word, nummuloidal, the remainder of Hyatt's description of the genus *Tripteroceras* will stand, with typical *Orthoceras hastatum* as the genotype.

The conch is strongly depressed dorso-ventrally. The cross-section is depressed subtriangular, with the ventral side distinctly

<sup>34</sup> Hyatt, A., op. cit., p. 287.

flatter than the dorsal. The lateral sides are rapidly rounded. The sutures form broad dorsal and ventral lobes. The lateral saddles are relatively high. Usually the conch is straight, though several specimens of *Orthoceras hastatum* are curved slightly lengthwise. In Hyatt's generic description the conch is described as having the whorl arcuate in the young.

### 30. TRIPTEROCERAS HASTATUM (BILLINGS)

PLATE XXXI, FIGS. 3A, B, C, D

*Orthoceras hastatum* Billings, Geol. Surv. Canada, Rep. Progr. for 1853-56, published in 1857, p. 333

Original Description: Shaped like a *Theca*, two-edged; ventral side broad and almost flat, slightly convex; dorsal aspect most convex along the center, thence sloping to the sides, which are perpendicular to the ventral aspect, and nearly flat in the larger portion of the shell. The section is thus a low, broad-based triangle, with the angle at each end truncated, and with the apical angle rounded. At a lateral diameter of eleven lines the height or dorso-ventral diameter is six lines; the rate of tapering is about 4 lines to the inch, measuring the inclination of the sides; the ventral and dorsal aspect approach each other at the rate of two lines and a-third to the inch; siphuncle small, close to the centre of the ventral margin; the septa are curved in a circle of which the radius is about half-an-inch, their distance from each other has not been satisfactorily ascertained; near the apex the sides consist of two rounded edges, but in the direction of the aperture these become more and more broadly truncated, until at a diameter of eleven lines they have a perpendicular width of about two lines. The surface is coarsely striated transversely, and, at the dorsal ridge, the striae appear to make a bend toward the aperture.

Locality and Formation.—Black River and Trenton limestone, Pauquette's Rapids, Ottawa City.

Five specimens, numbered 1281, and lettered *a*, *b*, *c*, *d*, and *e* respectively, are in the Victoria Memorial Museum. Of these, specimen 1281a is regarded here as the type, since it is 11 lines wide; a septum truncates its upper end. Specimen 1281c, with a septum at its lower end, comes next in size. Specimen 1281d, here figured, shows the lengthwise curvature at its apical end, with the concave curvature on its dorsal side; it is ter-

minated both at top and bottom by a septum. Specimen 1281b is smaller, but shows a similar lengthwise curvature. Specimen 1281e shows the apical end. (Specimen 1281 is described here as *Tripteroceras pauquettense*, and does not properly belong to the type series of *Orthoceras hastatum*.)

The conch of specimen 1281d, here figured, enlarges with a lateral apical angle of  $20^{\circ}$ . The ventral side is strongly flattened. The dorsal side shows a slight tendency toward angularity along its median line. From this median line toward the lateral angles, the dorso-lateral sides are slightly flattened. The lateral angles are abruptly rounded. Toward the apical end, the specimen is gently curved lengthwise. The sutures of the septa curve evenly downward on both the dorsal and the ventral sides. The siphuncle is close to the ventral side, but its structure is unknown. The lines of growth are almost directly transverse around the entire specimen, but on the ventral side their direction is very slightly concave upward, and on the dorsal side there is a corresponding but almost imperceptible concave curvature which is interrupted medially by an almost imperceptible convex curvature.

### 31. TRIPTEROCERAS PAUQUETTENSE SP. NOV.

PLATE XXXI, FIGS. 2A, B, C, D

Orthoceracone strongly compressed; at its upper end the lateral diameter is 24 mm. and the dorso-lateral one is 15 mm. The cross-section is slightly subtriangular, owing to the smaller convexity of the ventral side. The dorsal side is quite regularly rounded and forms about two-fifths of a circle having a radius of 13 mm., while the ventral side forms about one-fifth of a circle having a radius of 20 mm. The lateral margins are rapidly rounded. The center of the siphuncle is 4 mm. from the ventral wall. It enlarges from a diameter of 4 mm. at the septa to 5 mm. at mid-height within the camerae. Its passage through the septum is 1.5 mm. in diameter.

The specimen is 25 mm. in length. Six camerae occur in a length of 24 mm. On the ventral side of the conch, the sutures of the septa curve strongly downward toward the median line, but, on approaching the lateral outline of the conch, this curvature of the sutures becomes slightly convex. Along the median line of the ventral side the downward curvature of the sutures

is slightly angular. On the dorsal side of the conch, the downward curvature of the sutures is more moderately and more evenly concave. The lateral outlines of the conch diverge at an angle of  $11^{\circ}$ . No growth lines are preserved on the exterior of the shell.

Locality and Horizon.—Pauquette Rapids, in the Ottawa River, Canada; in the Leray member of the Black River.

Remarks.—The specimen here described is numbered 1281 in Victoria Memorial Museum, at Ottawa, Canada, and is there found among the types of *Orthoceras hastatum* Billings, from which it is here separated as a distinct species.

The specimen here described as *Tripteroceras pauquettense* probably is distinct generically from typical *Tripteroceras*. The latter probably contains only species with moderately expanded siphuncular segments, species with nummuloidal segments probably being referable to a distinct genus.

### 32. CHARACTOCERAS GEN. NOV.

Genotype: *Trochoceras* (?) *baeri* Meek and Worthen. Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 263; Meek, Geol. Surv. Ohio, Pal., 1, 1873, p. 157, pl. 13, fig. 9.

Conch nautiloid, depressed dorso-ventrally, the dorsal side being impressed at contact with the ventral side of the preceding volution. The transverse striae indicate that the margin of the aperture curved increasingly downward from the dorsal side of the conch toward its ventral side, the hyponomic sinus being broad and relatively deep, but not abrupt. The sutures of the septa curve moderately downward laterally, rising farther on the ventral than on the dorsal side. The siphuncle is located near the ventral side, but not in contact with the latter. The segments of the siphuncle are somewhat between subfusiform and elongate elliptical in outline.

The conch of *Uranoceras* Hyatt is compressed laterally, and there is no dorsal furrow, although adjacent volutions often are so close as to touch each other. The sutures of the septa are more sinuous laterally, at later stages of growth. The siphuncle is only slightly ventrad of the center of the conch, and the downward curvature of the septal necks is distinct. The form of the segments is elongate cylindrico-elliptical. The genotype is *Uranoceras uranum* Barrande, from the Silurian of Bohemia.

In *Litoceras* Hyatt, the cross-section of the conch is broadly kidney-shaped; the ventral side presents a semicircular outline, which rounds rapidly into the broadly impressed dorsal side of the conch. The siphuncle is located distinctly dorsad of the center, except in younger stages of growth. Since the genotype, *Litoceras whiteavesi* Hyatt, is from the Canadian of Newfoundland, it may be assumed that the segments of this siphuncle were curved cylindrical, and not elongate elliptical or subfusiform in outline. *Litoceras* does not occur in the Richmond formation.

*Charactoceras* includes also *Nautilus hercules* Billings, from the Charleston formation (Richmond) of Anticosti. *Eurystomites plicatus* Whiteaves, from the Lake Winnipeg area, apparently is congeneric.

33. CHARACTOCERAS BAERI (MEEK AND WORTHEN)

PLATE XXXI, FIG. 1; PLATE XXXII, FIGS. 1A, B; PLATE XXXIII, FIGS. 1A, B; PLATE XXXIV, FIGS. 1A, B, 2

*Trochoceras* (?) *Baeri* Meek and Worthen, Proc. Acad. Nat. Sci. Philadelphia, 1865, p. 263. Meek, Geol. Surv. Ohio, 1, 1873, p. 157, pl. 13, fig. 9.

*Type specimen*.—The type was collected at Richmond, Indiana. It consisted of a phragmacone, defective on one side, showing neither surface structure, nor the siphuncle. The dorsal side of each volution is impressed distinctly by the ventral side of the preceding volution. The type is illustrated in volume 1 of the Paleontology of Ohio, and in this volume it is stated that fragments from the same locality and position as the type have the siphuncle located rather more than its own breadth outside of the center. Better specimens, collected by Prof. W. H. Shideler from the Richmond at Oxford and vicinity are described in the following lines.

*Oxford specimens*.—Maximum diameter of the largest well preserved specimen found, (Plate XXXI, Fig. 1; Plate XXXII, Figs. 1 A, B; see also Plate XXXIII, Figs. 1 A, B), from the ventral margin of the aperture to the opposite side of the last volution, 150 mm.; diameter at right angles to the latter, also across the umbilicus, 113 mm. Lateral diameter of the living chamber at the base of the hyponomic sinus, 93 mm.; dorso-ventral diameter at the same point, 66 mm. Length of living chamber from suture at base to lower part of hyponomic sinus, measured along the ventral side, about 100 mm.; length to highest

part of the lateral margins of the aperture, measured along the median part of the lateral sides, about 108 mm. Depth of hyponomic sinus below level of highest part of lateral margins of aperture, 36 mm.

At the base of the hyponomic sinus the lateral diameter of the living chamber is 93 mm.; 100 mm. farther down, measured along the ventral side of the conch, this diameter is 83 mm.; 100 mm. still farther down it is 67 mm.; indicating a rate of diminution of 10 and 16 mm. respectively in the distances mentioned. Estimating the remainder of the length of the last volution, in an apicad direction, as 120 mm., the lateral diameter of the conch at the beginning of its last volution, was at least as small as 47 mm., but probably was smaller, since the rate of diminution of the lateral diameter of the conch appears to have been greater in an apicad direction. In fact, in some specimens, which show parts farther apicad, the rate of diminution of parts narrower than 47 mm. equals 25, and occasionally even 28 mm. in a length of 100 mm. The apical end of the conch has not been discovered, but it is estimated that the large conch here described included at least 2 complete volutions and possibly more or less of a third volution. The umbilicus may have been penetrated by a perforation about 10 mm. in diameter, but this part is not well preserved in any specimen.

The conch is depressed dorso-ventrally, the general outline of a cross-section of the larger volution being transversely elliptical, with the dorsal side distinctly and broadly impressed. The ratio of the dorso-ventral to the lateral diameter varies from 67% to 70% in different specimens. The ventral side is less strongly curved than the dorsal, the maximum curvature of the lateral sides being slightly nearer the ventral side of the whorl. In general, the lateral sides of the whorl converge toward the dorsal side. In one specimen, with a width of 66 mm. at the base of the living chamber, the width of the impressed zone at this point was 25 mm., its depth being 4 mm. In its original condition the conch was symmetrical, but, in the fossil state, one of the lateral sides often is flattened slightly or more distinctly; usually on that side of the specimen which, in the original position of the fossil in the rock, faced downward. In those specimens in which one of the lateral sides is flattened, the opposite side usually shows the normal transverse convexity.

The number of camerae in a length equal to the lateral diameter of the conch, varies in different specimens. In the large specimen described above, 7 camerae occur in this length, if measured along the ventral side of the conch. Specimens with 6 camerae in this length are more common, and a few specimens with 5 camerae in this distance occur. Close study fails to show any specific differences accompanying this variation in the relative number of camerae.

The sutures of the septa rise moderately from the dorsal toward the ventral side of the conch, the amount of this rise varying from slightly more than the height of one camera, along the ventral side, to about one and a half camerae. Along the lateral sides these sutures curve slightly downward, forming very shallow lobes, readily detected only toward the upper part of the phragmacone. Along the ventral side the sutures arch moderately upward, producing low, broad saddles. The middle part of these saddles tends to be less curved than the lateral parts, and in some specimens there is a faint downward curve of the sutures along the median line of the ventral side, but this is by no means a constant feature.

The septa are moderately concave, their curvature being greater dorso-ventrally than laterally. The siphuncle is located on the ventral side. Its distance from this side varies from one-fifth to two-sevenths of the dorso-ventral diameter.

In the specimen from Flat Fork, (Plate XXXIV, Fig. 2), three and a half miles northeast of Oregonia, Ohio, the center of the siphuncle is 5.5 mm. distant, where the dorso-ventral diameter is 36 mm. The segments of the siphuncle vary from 5.5 to 6 mm. in diameter dorso-ventrally, at mid-height of the camerae, diminishing to 4, or even 3 mm. where in contact with the septa, the passage through the septa being still narrower. Along the dorsal side of the siphuncle, the vertical outline of the segments is more evenly convex; but along the ventral side the vertical outline is distinctly convex above and concave below, the concave part being adnate to the septa beneath for a length of 3 to 5 mm. The upper part of the dorsal outline of some of the segments is adnate for a length of 1 to 3 mm. to the overlying septa, while in other segments no adnation is noted. The septal neck of this specimen appears to be very peculiar in construction. On the dorsal side of the siphuncle the septum maintains an even

rate of curvature as far as the most constricted part of the exterior wall of the siphuncle, and then appears to continue into the interior of the siphuncle for a distance of 1 mm., bending downward at an angle of  $25^{\circ}$  with a direct continuation of its course. On the ventral side of the siphuncle the septum curves gradually downward where in contact with the lower half or third of the overlying segment of the siphuncle, until reaching the most constricted part of the exterior wall of the siphuncle, beyond which it appears to extend into the interior of the siphuncle about half a millimeter in a direction toward the similar extension of the dorsal part of the septum. As a result the open passage through the center of the siphuncle appears to be constricted here to a narrow opening varying from 2 to 3 mm. in diameter. This constriction of the interior of the siphuncle, beyond the amount of constriction indicated by the exterior wall of this siphuncle, is not noted in all specimens, though traces of such constriction occur also in several of the segments in specimens obtained at Four Mile creek, near Oxford, Ohio. It is not regarded as a constant feature. Apparently it is not strictly a part of the septa, but was formed subsequent to the latter.

In some specimens from 8 to 10 of the upper camerae are considerably shorter in length than the camerae beneath, indicating a rather long period of gerontic growth.

The surface of the shell is transversely striated by lines which tend to occur at regular intervals, about 16 in a length of 20 mm. where the lateral diameter is 85 mm. Since similar distances obtain also toward the apical end, where the diameter is much less, the striae here appear relatively more distant. In some specimens the striae are more numerous, equalling 20 and even 24 in a length of 20 mm. In general, these striae are of the "banded" form, or they may be very narrow and sharply defined, and separated by much broader flat areas. These transverse striae follow the same course as the former limits of the aperture. Along the median part of the dorsal side they are nearly directly transverse, but dorso-laterally they curve increasingly downward, their ventral course being broadly concave, forming broad and deep lobes here, whose bases lie about 5.5 camerae below the level of these striae on the dorsal side of the conch. These lobes mark former positions of the hyponomic sinus.

*Locality and Horizon.*—This species was described from Rich-

mond, Indiana. The large specimen forming the basis of most of the description here presented was obtained on Dodge's Fork, near Oxford, Ohio, at the base of the Whitewater member of the Richmond formation. Numerous specimens from the same horizon, on Little Four Mile creek, also near Oxford, furnished additional material, including sections of the siphuncle. However, most of the details of the structure of the siphuncle here presented were obtained from a specimen collected by Prof. J. E. Carman on Flat Fork, three and a half miles northeast of Oregonia, Ohio, at the base of the Whitewater. The specimens from the vicinity of Oxford belong to Miami University and were collected by Professors W. H. Shideler and S. R. Williams.

A closely similar, if not identical, species occurs at the base of the *Rhynchotrema dentata* bed in the Upper Whitewater, on Beasley Run, north of Camden, Ohio.

Specimens resembling *Charactoceras baeri* occur in the Fernvale member of the Richmond at Wilmington, Illinois, and Cape Girardeau, Missouri.

#### 34. ONCOCERAS HALL

Genotype: *Oncoceras constrictum* Hall. Pal. New York, vol. 1, 1847, p. 197, pl. 41, figs. 6 a-f, 7 a-d

Conch curved lengthwise; the lengthwise curvature of the ventral side is convex, and the general curvature of the dorsal side is concave, but along the upper part of the phragmacone and the lower part of the living chamber the vertical outline of the dorsal side changes to distinctly, though moderately, convex. The gibbosity of the dorsal side of the conch usually extends also laterally sufficiently to be noticeable when the conch is examined from the ventral side. The conch is slightly compressed laterally. The living chamber narrows toward the aperture, which is broadly oval in outline, the angularity being on the ventral side. The hyponomic sinus is shallow. The siphuncle is close to the ventral wall of the conch, and its segments are narrowly fusiform.

*Oncoceras abruptum* Hall, *Gomphoceras cincinnatiense* Miller, *Oncoceras douglassi* Clarke, *Oncoceras pristinum* Ruedemann, and *Orthoceratites trentonense* Emmons are congeneric. The last named species from the Trenton of New York apparently is identical with *Oncoceras constrictum*. *Gomphoceras faberi*

Miller may belong here, though its dorsal outline is only faintly convex.

35. ONCOCERAS CONSTRICTUM HALL

PLATE XXXIX, FIGS. 2A, B, 3, 4

*Oncoceras constrictum* Hall, Pal. New York, vol. 1, 1847, p. 197, pl. 41, figs. 6 a-f, 7 a-d

*Type*.—Among the specimens figured by Hall that represented by figures 6 a, b, c may be selected as the type, not only because it is the first in the series of illustrations, but also because it is the largest, and evidently is a fairly typical example of the species as now known.

Conch curved lengthwise, slightly compressed laterally, and distinctly gibbous at the base of the living chamber and the top of the phragmacone, the gibbosity being conspicuous dorsally as well as laterally and ventrally. The radius of convex curvature of the vertical ventral outline is 30 mm. for the greater part of the length of the specimen, but at its apical end the rate of curvature is slightly greater. The dorsal side has a general concave curvature with a radius of 45 mm., but for a distance of 8 or 9 mm. both above and below the base of the living chamber the dorsal outline changes to slightly convex, producing a conspicuous gibbosity here. Toward the apical end of the specimen the rate of concave curvature increases to a radius of less than 20 mm.

The conch is compressed laterally. At the base of the living chamber, where the dorso-ventral diameter is 24 mm., the lateral diameter is 20 mm. Toward the aperture the conch contracts not only dorso-ventrally but also laterally. At the aperture the dorso-ventral diameter is 18 mm. Since the living chamber of the specimen here described is crushed laterally, it is not suitable for showing the rate of lateral contraction toward the aperture, but in better preserved specimens the rate of contraction laterally is greater than that dorso-ventrally, resulting in a slightly oval outline of the aperture. The curvature of the conch in a transverse direction is even on the dorsal side of the conch, but tends to be faintly angular on the median part of the ventral side.

The base of the living chamber is exposed by a fracture. The height of the living chamber is about 20 mm. That part of the phragmacone which remains attached to the living chamber is

24 mm. long. At the broken base the dorso-ventral diameter is 12 mm.

The septum at the base of the specimen curves gently dorso-ventrally, and curves even less laterally. The result is that the sutures of the septa form comparatively shallow lateral lobes. Along the dorsal side of the conch the sutures are almost directly transverse, but along the ventral side they rise into more or less distinctly angular saddles. The siphuncle is small, and is located less than 1 mm. from the ventral wall even along the upper part of the phragmacone. The number of camerae in a length equal to the dorso-ventral diameter in another specimen is about 8, and in still another specimen the segments of the siphuncle are seen to be narrowly fusiform.

*Figured specimens.*—The original<sup>35</sup> of figures 3 a, b, on plate 3 of the Third Report of the New York State Museum, published in 1850, shows the surface striae very well. These striae are directly transverse along the dorsal and lateral sides of the conch as far as the middle of the lateral sides. Ventrad of these middle points the transverse lines curve gradually downward until they meet along the median part of the ventral side at an angle of about 130° in the vicinity of the aperture. The hyponomic sinus is broadly V-shaped, and its depth equals 2 or 3 mm. Judging from these transverse striae, the aperture was about 15.5 mm. long, dorso-ventrally, 12.5 mm. wide, and had a distinctly angular outline at the hyponomic sinus.

The strongly concave lengthwise curvature of the upper part of the dorsal outline of the living chamber in the specimens represented by figures 6d and 6e, on the plate accompanying the original description, probably is due in large part to pressure, both specimens being preserved in a rather soft argillaceous limestone.

In some specimens the cast of the interior of the phragmacone and of the lower half of the living chamber is marked by about 35 faint vertical ribs, none of which correspond to any structure on the exterior of the shell.

*Locality and Horizon.*—All of the specimens described here are from Middleville, New York, in the Trenton limestone. Numbered 824 in the American Museum of Natural History.

<sup>35</sup> This Journal, Pl. XXXIX, figs. 2A, B.

## 36. MAELONOCERAS HYATT

Genotype: *Phragmoceras praematurum* Billings

Laterally compressed cyrtoceracones, with the ventral side more narrowly rounded than the dorsal. The living chambers are short, and their apertures, in the typical specimens, are contracted and pear-shaped. The sutures of the septa curve slightly downward laterally. The siphuncle is near the ventral side, and its segments are narrowly fusiform.

*Cyrtoceras metellus* Billings from the Canadian of Point Levis, in the province of Quebec, *Cyrtoceras falx* Billings from the Black River of Pauquette Rapids, in Ontario, and *Cyrtoceras arcticameratum* Hall from the Guelph of Ontario are not congeneric with *Maelonoceras praematurum*. Possibly the form figured by Whitfield under *Cyrtoceras camurum* (Geol. Wisconsin, 4, 1882, p. 231, pl. 7, figs. 7-9) is a true *Maelonoceras*.

## 37. MAELONOCERAS PRAEMATURUM (BILLINGS)

PLATE XXXIX, FIGS. 6A, B, C; PLATE XLI, FIG. 7

*Phragmoceras praematurum* Billings; Canadian Naturalist, vol. 5, 1860, p. 163, figs. 20

*Maelonoceras praematurum* Hyatt; Proc. Boston Soc. Nat. Hist., vol. 22, 1884, p. 280

Two specimens belong to the set described by Billings under the name *Phragmoceras praematurum*, and both were figured. The specimen represented by figure 20, accompanying the original description, shows most of the details included in this description, and hence is here regarded as the type.

Type.—Conch strongly compressed laterally, and strongly curved length-wise, the siphuncle being close to the ventral side. The conch attains its greatest dimensions 5 mm. above the base of the living chamber. Here its lateral diameter is 16 mm. and its dorso-ventral one is 18.5 mm. The conch is more narrowly rounded on its ventral side, the radius of transverse curvature here being 5 or 6 mm., while that of the dorsal side is 8 mm. The convex lengthwise curvature of the ventral side has a radius of 25 mm., and that of the concave curvature of the dorsal side is about the same, at least within the limits of the type specimen.

The latter consists of the living chamber with 5 complete camerae attached. In addition, parts of 2 camerae prolong the dorsal outline of the specimen. The upper half of the living chamber narrows toward the aperture, where the lateral diameter is

12 mm., and the dorso-ventral one is 14 mm. In addition, the aperture is narrowed by two low but distinct ventro-lateral saddles, which rise above the level of the dorsal outline of the aperture and converge more or less toward each other. In the vicinity of these saddles the dorso-ventral parts of the living chamber are more or less flattened. The general outline of the aperture is pear-shaped, with the narrow part on the ventral side.

The upper part of the interior of the living chamber is distinctly constricted by a thickening of the shell. Along the dorsal and lateral sides of the aperture this thickening begins 3 mm. beneath the margin; along the ventral side it begins about 1 mm. beneath the aperture.

Along the ventral side, 5 camerae occupy a total length of 13 mm. The sutures of the septa rise slightly from the dorsal toward the ventral side of the conch. The sutures are nearly straight, their downward curvature along the lateral sides of the phragmacone being very faint. The general concavity of the septa is slight, equalling scarcely 1 mm. The siphuncle is about one-third of a millimeter from the ventral wall. Its lateral diameter, where passing through the septa, is 0.7 mm., widening to about 0.9 mm. within the camerae, the general form of its segments being only slightly fusiform.

The shell is relatively thick, equalling nearly 1 mm. along the dorsal and dorso-lateral parts of the upper half of the living chamber, and nowhere thinning to less than half a millimeter.

The transverse striae are merely lines of growth. Along the lower half of the living chamber these lines are almost directly transverse along the dorsal half of the circumference of the chamber; but on the ventral side they curve distinctly downward as far as the median part of this side. However, toward the upper part of the living chamber, the transverse striae rise more and more strongly from the dorsal toward the ventro-lateral parts of the conch, outlining successive stages in the development of the ventro-lateral saddles, which gradually increase in prominence until they attain an elevation of 2.5 to 3 mm. above the general level attained by the aperture along its dorsal side. From the crest of these saddles the lateral margins of the hyponomic sinus slope diagonally downward as far as its ventral end which descends 1 mm. or more beneath the general level attained by the dorsal side of the aperture. The general form of

the aperture is pear-shaped, with the narrow end on the ventral side. There is a tendency toward parallelism between the lateral walls of the hyponomic sinus, somewhat as in *Gomphoceras*.

*Locality and horizon.*—Black River limestone on LaCloche Island, in northern Lake Huron. Specimen No. 1294 in the Victoria Memorial Museum, at Ottawa, Canada.

38. MAELONOCERAS BILLINGSI SP. NOV.

PLATE XXXIX, FIGS. 5 A, B, C

*Phragmoceras praematurum* Billings, Canadian Naturalist, vol. 5, 1860, p. 163, fig. 19 only

The second specimen figured by Billings under the name *Phragmoceras praematurum* differs from the one here described as the type in having a shorter and straighter living chamber. It is assumed that the conch was much less curved lengthwise. Moreover, the dorsal half of the aperture is more nearly circular and the lateral walls of the hyponomic sinus are more nearly parallel.

*Locality and horizon.*—Lacloche Island, in the northern part of Lake Huron, in the Black River formation. Specimen No. 1294a, in the Victoria Memorial Museum, at Ottawa, Canada.

39. BELOITOCERAS GEN. NOV.

Type: *Oncoceras pandion* Hall

The group of conchs typified by *Oncoceras pandion* differs from typical *Oncoceras* in lacking a distinct gibbosity along the upper part of the phragmacone and the lower part of the living chamber. If any gibbosity along the dorsal side is present, the maximum development of this gibbosity is distinctly above the level of the base of the living chamber. Moreover, compared with typical *Oncoceras*, the conch is distinctly more flattened laterally.

The relationship of the group typified by *Oncoceras pandion* is with *Maelonoceras* rather than with *Oncoceras*. Like the latter, it is more strongly flattened laterally, and the interior of the living chamber is thickened below the margin of the aperture by an inner band which leaves a conspicuous contraction along casts of the interior of the conch. The aperture has an outline corresponding to that possessed by *Maelonoceras* during its earlier stages of growth, before the ventro-lateral saddles begin

to develop. In other words, *Beloitoceras* may be regarded as the stock from which *Maelonoceras* developed.

*Cyrtoceras carrollense* Worthen, *Oncoceras carvieri* Clarke, *Cyrtoceras fragile* Billings, *C. houghtoni* Clarke, *C. huronense* Billings, *C. isodorus* Billings, *C. norwoodi* Clarke, and *C. scofieldi* Clarke are congeneric; probably also an equal number of other described species of which the living chamber is not well known.

*Cyrtoceras dunleithense* Miller and Gurley, and *C. cordatum* Parks are characterized by the ridge-like protrusion of the siphonated side of the conch, and for these the generic term *Dunleithoceras* is proposed.

#### 40. BELOITOCERAS PANDION HALL

PLATE XXXVI, FIGS. 5 A, B; PLATE XLI, FIGS. 4 A, B, C

*Oncoceras pandion* Hall; Rep. Sup. Geol. Surv. Wisconsin, 1861, p. 45, *ibid*, 1862, p. 41, fig. 3

*Oncoceras pandion* Whitfield; Mem. Amer. Mus. Nat. Hist., vol. 1, pt. 2, 1895, p. 69, pl. 9, figs. 21, 22

•Type.—Conch strongly curved lengthwise, especially along its ventral side, where the radius of convex curvature is only 30 mm. Along the dorsal side the radius of concave curvature is 40 mm. The specimen enlarges from a dorso-ventral diameter of 19 mm. at its base to 25 mm. at the base of the living chamber. It diminishes to 22.5 mm. along a line drawn from 10 mm. above the base of the dorsal side of the living chamber to 14 mm. above the base of this chamber on the ventral side. Then this diameter diminishes rather abruptly, to 21 mm. within a distance of 3 mm., and to 20 mm. within an additional distance of 4 mm., above which the margin of the aperture is assumed to be. The corresponding lateral diameters are 16 mm. at the base of the specimen, 23 mm. at the base of the living chamber, 20 mm. where the abrupt contraction of the upper part of the living chamber begins, 16.5 mm. at a point 3 mm. farther up, and slightly less at the aperture. The sudden constriction of the cast of the interior of the living chamber near the aperture indicates the presence of a corresponding thickening of the interior of the wall of this chamber just beneath the aperture.

There is no trace of a gibbosity along the dorsal outline of the conch at the base of the living chamber, though the amount of concave curvature here is distinctly less. The cross-section of the conch tends to be slightly more narrowly convex on the ven-

tral than on the dorsal side, especially toward the living chamber, and most of all at its aperture, where the difference is strongly marked, resulting in the oval outline of the aperture. Faint, low, broad vertical ribs mark the cast of the interior of the conch; these number about 5 in a width of 11 mm., near the top of the phragmacone.

The number of camerae in a length equal to the dorso-ventral diameter, at the top of the series of camerae counted, is 7, when counted along the ventral side of the conch. The sutures of the septa are only slightly concave, most of the curvature being ventrad of the center of the conch. At the base of the specimen the upward curvature of the sutures is chiefly ventrad of the ventro-lateral sides. Toward the top of the phragmacone the upward curvature of the sutures begins progressively nearer the middle of the lateral sides, and the amount of the upward curvature on this ventrad side also becomes greater, the ventral saddles becoming successively higher. The siphuncle is almost in contact with the ventral wall of the conch. Its maximum width at the bottom of the specimen, within the camerae, is 3 mm., diminishing to about 1 mm. where it passes through the septa.

*Locality and horizon.*—Beloit, Wisconsin; in the buff part of the Black River dolomite.

Specimen No. 998, in the American Museum of Natural History.

*Mineral Point specimen.*—In addition to the type of *Oncoceras pandion*, Whitfield figured also a similar specimen (his figure 20) from a very fine-grained grayish rock at Mineral Point, Wisconsin. Lithologically this rock resembles that enclosing the type of *Cyrtoceras neleum*, from Platteville, Wisconsin. The Mineral Point specimen is more compressed laterally, the dorso-ventral and lateral diameters at the base of the living chamber being 26.5 and 21.5 mm. respectively. Apparently the conch is less strongly curved lengthwise, and the sutures of the septa curved less strongly upward on the ventral side. The uppermost camera is distinctly shorter than those beneath, the specimen being mature. The ventral side of the conch is more narrowly convex in cross-section than the dorsal side, especially toward the living chamber, and most of all near the aperture.

*Janesville specimen.*—In the specimens from Janesville, Wis-

consin, figured by Clarke,<sup>36</sup> the lengthwise curvature of the ventral side of the conch is similar, but the concave curvature of the dorsal side is greater, especially along the lower part of the living chamber; the conch is more compressed laterally, and the sutures do not rise as strongly on the ventral side of the phragmacone.

*Oncoceras carvieri* Clarke<sup>37</sup> appears to be closely related to the Platteville specimen figured by Whitfield under *Oncoceras pandion*. It is characterized chiefly by its lateral compression, and the fact that the living chamber is not so strongly contracted toward the aperture.

#### 41. BELOITOCERAS PLEBEIUM HALL

PLATE XXXVI, FIGS. 4A, B, 3A, B; PLATE XLI, FIGS. 5A, B  
*Oncoceras plebeium* Hall; Rep. Superintendent Geol. Surv. Wisconsin,  
1861, p. 44

*Oncoceras plebeium* Whitfield, Mem. Amer. Mus. Nat. Hist., vol. 1, pt. 2,  
1895, p. 68, pl. IX, figs. 16-19

The original description indicates that several specimens were at hand at the time of description of this species. Of these Whitfield figured three. The largest is selected as the type because it bears the small lozenge-shaped yellow label, and retains a remnant of the thin paper label which Hall used for indicating his types among the species described in 1861. Moreover, this specimen is the first one of the three figured by Whitfield.<sup>38</sup>

*Selected type.*—Specimen (Plate XXXVI, Figs. 4A, B; Plate XLI, Figs. 5A, B) consisting of the living chamber with 7 camerae still attached. Conch rather strongly curved lengthwise in a dorso-ventral plane; the radius of convex curvature of the ventral side, along the upper part of the phragmacone and along the living chamber, is 45 mm.; the radius of concave curvature of the dorsal side, along the upper part of the phragmacone, is 30 mm.; a very faint convexity extends from the base of the second camera below the living chamber upward along the greater part of the living chamber, but within 3 or 4 mm. from the aperture the dorsal outline is slightly concave again. The faint convexity along the lower part of the dorsal side of the liv-

<sup>36</sup> Clarke, John M., The Lower Silurian Cephalopoda of Minnesota; Minn. Geol. Survey, Final Rept., vol. 3, pt. 2, p. 799, pl. 58, figs. 4-6a, 1897.

<sup>37</sup> Idem. p. 799, pl. 58, figs. 7-9.

<sup>38</sup> Whitfield, R. P., Republication of descriptions of fossils from the Hall collection; Mem. Am. Mus. Nat. Hist., vol. 1, pl. 9, figs. 15, 16, 1895.

ing chamber is supposed to correspond to the much more pronounced gibbosity of *Oncoceras constrictum* Hall, but it is located farther up.

The dorso-ventral diameter enlarges from 19 mm., at the base of the specimen, to 22 mm. at the base of the living chamber, the latter being 19 mm. farther up along the ventral side of the conch. At mid-height of the living chamber this dorso-ventral diameter is still 22 mm., but at the constricted part, 3 mm. below the aperture, it is only 20 mm., enlarging slightly above this point. Since the specimen is a cast of the interior of the shell, the apparent enlargement of the living chamber near its aperture may be due chiefly to a thickening of the interior of the shell there, the exterior of the shell not showing any corresponding expansion.

The conch is strongly compressed laterally, the lateral diameter at the base of the specimen being 15 mm.; at the base of the living chamber it is 18 mm.; about 2 mm. above this base it is 18.5 mm.; and from this point upward it diminishes gradually, until 3 mm. below the aperture, at the constricted part, it is 15.5 mm.; above this constricted part it increases slightly. The broadest part of the cross-section of the conch is distinctly dorsad of its center, the ventral side being much more narrowly rounded than the dorsal one, especially toward the aperture, whose contour is distinctly oval in outline.

The sutures of the septa are directly transverse along the dorsal side of the phragmacone, and this direction is maintained along the dorso-lateral parts of the conch; but, on approaching the middle of the lateral sides, the sutures curve progressively more strongly upward, until they form an angle of about  $75^{\circ}$  with the ventral outline, when the cast of the interior of the phragmacone is viewed from one of the lateral sides. The result is the formation of distinct saddles along the ventral side of the conch. The number of camerae, in a length equal to the dorso-ventral diameter of the conch at the top of the series of camerae being counted, is 8, when the counting is done along the ventral side. When compared with the corresponding lateral diameter, this number of camerae is slightly greater than 6. The septa are only moderately concave. The exterior of the cast of the interior of the phragmacone is marked by faint traces of vertical ribs, most readily detected on the dorsal side of the cast.

The siphuncle is almost in contact with the ventral wall of the conch; it is moniliform in structure; its maximum diameter within the camerae is 2.2 mm., diminishing to 1.5 mm. at its passage through the septa.

*Smaller specimen figured by Whitfield.*—This specimen (Plate XXXVI, Figs. 3A, B) is illustrated by figures 18 and 19 among the series published by Whitfield. It consists of the living chamber with 9 camerae still attached. It is closely similar in form to the larger specimen figured by Whitfield, but its dorso-ventral diameter at the base of the living chamber is only 17 mm. instead of 22 mm., and its lateral diameter is largest (15.5 mm.) fully one-third of the height of the living chamber above its base, where the diameter is 14.5 mm. The phragmacone appears to enlarge more rapidly in size, and the concave curvature of the sutures of the septa along the middle of the lateral sides is much less conspicuous. On the contrary, these sutures rise slightly even along the dorso-lateral sides of the phragmacone and their rise is only moderately accentuated along the middle of the lateral sides, but they form about the same angle with the ventral outline of the phragmacone. In the smaller, as well as in the larger specimen here described, the sutures form progressively more acute angles on approaching the upper part of the phragmacone.

*Phragmacone figured by Whitfield.*—This specimen is illustrated by figure 17 of the series published by Whitfield. It apparently belonged to a mature individual, judging from the distinct shortening of the uppermost camera, compared with the camerae immediately beneath. Evidently, even the uppermost camera of the phragmacone is preserved. It is significant, therefore, that the dorso-ventral diameter at the top of the specimen is only 17 mm., in this respect agreeing more readily with that of the smaller specimen figured by Whitfield. The sutures of the septa rise even more strongly toward the ventral side of the conch. The height of the camerae is distinctly greater, 7 camerae occurring in a length equal to the dorso-ventral diameter, in place of 8, when this length is measured along the ventral side of the shell and the dorso-ventral diameter is measured at the top of the series of camerae being counted.

*Other specimens.*—The Hall collection at the American Museum of Natural History includes five specimens in addition to

those figured by Whitfield. Two of these retain enough of the living chamber and of the attached part of the phragmacone to be referred with confidence to *Oncoceras plebeium*. One of these has a dorso-ventral diameter of 17 mm. at the base of the living chamber, the other of 19.5 mm. A third specimen consists of a body chamber, expanding toward the aperture as in *Cyrtorizoceras minneapolis* (Clarke) and *Cyrtorizoceras scofieldi* (Clarke). Not enough remains of the other two specimens to make their relationship to *Oncoceras plebeium* certain.

*Locality and horizon.*—Described from the "Buff limestone of the Trenton limestone group, at Beloit," Wisconsin. According to Bassler's Bibliographic Index, the horizon of this species is the Platteville member of the Black River.

Types, No. 996, American Museum of Natural History, in New York City.

*Margin of the aperture.*—One of the specimens in the American Museum of Natural History apparently presents features both of the exterior and of the interior of the upper part of the shell, but its chief interest lies in the fact that it retains a sharp outline of the margin of the aperture. This margin is most elevated along the middle of the lateral sides, and from this point it slopes slightly downward both toward the dorsal and toward the ventral side; however, the slope toward the ventral side of the conch is slightly greater than that toward the dorsal side, compared with the direction of the central axis of the living chamber. The hyponomic sinus evidently is very shallow. When viewed from above, however, the aperture contracted distinctly ventrad of its center, as in the type of *Oncoceras plebeium*.

Along the dorsal half of the specimen, the living chamber is contracted slightly but distinctly at a level about 5 or 6 mm. below the margin of the aperture. Toward the ventral side this contraction is scarcely 4 mm. from the margin of the aperture. Above this point of contraction the specimen retains about the same dimensions as far as the aperture. Since no trace of the septa is shown by the specimen, this contraction appears to be a feature of the exterior surface of the shell as well as of its interior, but ordinarily it would be regarded as characteristic of the interior of the living chamber alone, due to a thickening of the interior of the shell along the line indicated.

Judging from the contours of the specimen, the height of the

living chamber, along the middle of its lateral sides, is 20 mm.; and the dorso-ventral diameter at this point is 20 mm., diminishing to 19 mm. at the aperture.

This specimen is numbered 999B in the American Museum of Natural History, and is incorrectly associated under this number with *Oncoceras lycus*. It was obtained at Beloit, Wisconsin, at the same locality and horizon with the type of *Oncoceras plebeium*.

*Oncoceras lycum* Clarke<sup>39</sup> appears to be closely similar to *Oncoceras plebeium*, as far as may be determined from the figures. The increase in concave curvature of the dorsal side near the aperture and the straightening of the shell along the middle and lower part of the dorsal side of the living chamber is characteristic; the distance between the septa is similar; also the course of the sutures.

*Cyrtoceras houghtoni* Clarke<sup>40</sup> may be the same as the smaller specimen figured by Whitfield under *Oncoceras plebeium*. In both figures 13 and 15 there is apparently a very faint trace of a straightening or swelling along the lower two-thirds of the living chamber. Moreover, the sutures of the septa are about the same distance apart. The extreme lateral compression of the conch shown by figures 14 and 14a is regarded as due to fossilization, and not as characteristic of the shell in its original state.

#### 42. BELOITOCERAS LYCUM (HALL)

##### PLATE XXXVI, FIGS. 2 A, B

*Oncoceras lycum* Hall; Rep. Superintendent Geol. Surv. Wisconsin, 1861, p. 45

*Oncoceras lycus* Whitfield; Mem. Amer. Mus. Nat. Hist., vol. 1, pt. 2, 1895, p. 69, pl. IX, figs. 13, 14

Specimen consisting of a living chamber with 10 camerae still attached. Conch moderately curved lengthwise in a dorso-ventral plane; the radius of convex curvature of the ventral side of the phragmacone and of the lower half of the living chamber is 55 mm.; the radius of concave curvature of the dorsal side of the phragmacone is 40 mm. For a distance of 5 or 6 mm. below the base of the living chamber, and for an equal distance above the base, the dorsal outline of the conch is nearly straight lengthwise, suggesting a slight gibbosity of the dorsal outline of the lower

<sup>39</sup> Clarke, op. cit., p. 799, pl. 58, figs. 1-3a.

<sup>40</sup> Idem. p. 807, pl. 59, figs. 12-15.

half of the living chamber, followed by a slightly concave lengthwise curvature along the upper half of this living chamber, in a normal shell, somewhat as in *Oncoceras plebeium* Hall, from the same locality and horizon as the type of *Oncoceras lycum*.

The specimen is a cast of the interior of the conch. In this specimen the cast of the interior of the living chamber is contracted abruptly and strongly near mid-height. The contraction begins about 8 mm. above the base of this chamber and reaches its maximum at 10 mm. above this base; above this level of maximum contraction the cast expands evenly as far as the aperture. The dorso-ventral diameter of this cast, at the base of the living chamber, is 17 mm.; 8 mm. above the base it is 18 mm.; at the most narrowly contracted part of the chamber it is 15 mm.; and from this point of greatest contraction the cast of the interior enlarges evenly to approximately 17 mm. at the aperture, as far as can be determined from that part of the aperture which is preserved. This abrupt and strong contraction of the cast of the interior of the living chamber may not be indicative of any corresponding contraction of the exterior of the shell. On the contrary, it may be confined to its interior, and may be due to a very gerontic thickening of the interior of the living chamber, at mid-height, in case of some individual specimen; or, the animal after death may have contracted along the upper half of the living chamber, as appears to have been the case not infrequently in some Silurian Poterioceroids. The symmetrical contraction of this cast favors the first one of these views, namely that the walls of the conch were thickened above mid-height by a gerontic deposit upon their interior surface. If this was the case, then the exterior of the living chamber may have contracted toward its aperture very much as in *Oncoceras plebeium*, from the same horizon and locality. In fact, *Oncoceras lycum* may have differed from the type of *Oncoceras plebeium* chiefly in its smaller curvature lengthwise, and in the greater height of the camerae.

The phragmacone enlarges from a dorso-ventral diameter of 11 mm. at its base to 17 mm. at its top; the length of the phragmacone, measured along its ventral side, is 22 mm. According to this rate of tapering, the total length of the conch probably did not exceed 75 mm., when measured along its ventral side. The lateral diameter of the specimen at its base is 9.8 mm., and

at the top of the phragmacone it is 15.5 mm., indicating a moderate lateral compression of the conch. There is a slight tendency toward angularity in the cross-section of the conch, along the median line of its ventral side, especially toward the top of the phragmacone.

Counting along the ventral side of the conch, there are 7 camerae in a length equal to the dorso-ventral diameter of the conch at the top of the series of camerae being counted. The sutures of the septa are directly transverse on the dorsal and dorso-lateral sides of the conch, but they curve upward on approaching the ventral side of the conch, producing low ventral saddles.

The siphuncle is close to the ventral wall of the conch. At the base of the specimen, the diameter of the siphuncle, where it passes through the septum, is slightly over 1 mm. Very faint vertical ribs, easily escaping attention, mark the cast of the interior of the phragmacone.

*Locality and horizon.*—Described from the "Buff limestone of the Trenton limestone group;" referred by Bassler, in his Bibliographic Index, to the Platteville member of the Black River. The type specimen is labelled as coming from Beloit, Wisconsin.

*Holotype.*—No. 999, American Museum of Natural History, in New York City.

*Remarks.*—The appearance of greater height in the camerae is due chiefly to the small curvature of the conch lengthwise, owing to which the septa are less closely crowded together on the dorsal side of the conch, measuring only 5.5 camerae in a length of 10 mm., instead of 8 camerae as in the smaller specimen of *Oncoceras plebeium* figured by Whitfield.

#### 43. WESTENOCERAS GEN. NOV.

*Genotype:* *Cyrtoceras manitobense* Whiteaves. Trans. Royal Soc. Canada, vol. 7, sec. 4, 1890, p. 80, pl. 13, figs. 3-5; pl. 15, fig. 4

Conch slender, sub-fusiform, nearly straight along the dorsal side, except at the aperture, but distinctly curved along the ventral side. Aperture oblique, inclining downward from the ventral toward the dorsal side. Sutures of the septa curving strongly downward laterally, but rising dorsally and ventrally into distinct saddles, which rise higher on the ventral than on the dorsal side. Siphuncle nearer the ventral than the dorsal side, described as "nearly cylindrical, but very slightly expanded between the septa and as slightly contracted where it intersects

them." Further study of typical specimens is necessary to determine the exact structure of the siphuncle.

#### 44. POTERIOCERAS McCOY

Genotype: *Orthoceras fusiforme* Sowerby. See Foord, Carb. Foss, Ireland, pl. 15

The name *Poterioceras* was proposed by McCoy for certain Carboniferous species, the generic description being: "Shell fusiform. Mouth contracted. Siphuncle dilated between the chambers, excentric." Blake states that the diagram accompanying this description is not justified by any known species, and represents the aperture as very small but simple.

The species mentioned first in the body of the text is *Poterioceras fusiform* (Sowerby)<sup>41</sup> from Boland, Kildare. This was founded on a specimen 6 inches long, 6 lines wide at the small end, one inch and 7 lines wide at its largest diameter, and 9 lines wide at the aperture.

A study of a specimen from Kildare, Ireland, numbered 2177 in the Museum of Comparative Zoology at Harvard University, (Plate XLI, Figs. 1A, B) indicates the following characteristics:

Conch fusiform, curved lengthwise, with the ventral side convex, and the dorsal side concave, except along the upper part of the phragmacone and the lower part of the living chamber along the dorsal side, where the outline is distinctly convex or gibbous. Toward the base of the living chamber the sutures rise from the ventral toward the dorsal side of the conch. The siphuncle is located a short distance ventrad from the center of the conch. The septal necks are short and curve distinctly downward and outward. The connecting rings are elongate elliptical in outline. The aperture appears to have been circular in outline and its margin directly transverse. There may have been a shallow hyponomic sinus, but this is not indicated by the specimen at hand. Conchs of this type do not occur in Silurian or Ordovician strata.

*Poterioceras fusiform* (Sowerby) was figured by Foord<sup>42</sup> and one of his illustrations is reproduced herewith (Plate XL, fig. 2). *Poterioceras latiseptum* Foord<sup>43</sup> likewise shows the rise of the sutures of the septa from the ventral toward the dorsal side of

<sup>41</sup> Sowerby, Mineral Conchology, pl. 588, figs. 1, 2.

<sup>42</sup> Foord, Carb. Ceph. Ireland, 1897, pl. 15.

<sup>43</sup> Idem, pl. 16.

the conch. The siphuncle is between the center of the conch and its ventral wall, and the segments of this siphuncle are more nearly circular or slightly elongate in outline. *Poterioceras ventricosum* McCoy apparently presents a different contour from typical *Poterioceras*, as based on *fusiforme*.

#### 45. AMPHICYRTOCERAS GEN. NOV.

Genotype: *Cyrtoceras orcas* Hall

Conch subfusiform, but curved lengthwise and depressed dorso-ventrally. The ventral side of the conch is curved convexly, and the dorsal side is concave except toward the upper part of the phragmacone and the lower part of the living chamber, along which it is gently convex or distinctly gibbous. The living chamber contracts toward the aperture, and the margin of the latter is nearly directly transverse dorsally and laterally, but curves gently downward toward the median line of the ventral side, where a shallow hyponomic sinus is located. The siphuncle is near the ventral wall of the conch, but not in actual contact with it. The septal necks curve distinctly downward, and the connecting rings tend to be almost cylindrical in form, except at their upper and lower extremities, where they contract abruptly.

The genotype, *Cyrtoceras orcas* Hall, is relatively common in the Racine member of the Niagaran, at Racine, Waukesha, and elsewhere in Wisconsin. *Cyrtoceras laterale* Hall, from the same area and horizon, is congeneric. *Oncoceras pettiti* Billings, and possibly *Oncoceras thales* Billings from the Niagaran of Ontario also belong here. *Strepoceras janus* Billings and *Streptoceras heros* Billings differ in having a protruding hyponomic sinus, like an incipient lip.

#### 46. AMPHICYRTOCERAS ORCAS (HALL)

PLATE XXIX, FIGS. 1 A, B, C

*Cyrtoceras orcas* Hall; Rep. Superintendent Geol. Surv. Wisconsin, 1862, p. 43

*Oncoceras orcas* Hall; 20th Rep. New York State Cab. Nat. Hist.,  
1868, p. 350, pl. 17, figs. 1, 2

The type of this species, measured along the curvature of its ventral side, is 143 mm. long. The living chamber appears to occupy 57 mm. of this length, but there is a possibility that one camera, whose upper septum is not exposed, is included in this measurement. The upper three exposed camerae occupy a length of 30 mm.; the next three, 29 mm.; and the lowest three,

27 mm. At the uppermost exposed septum, the greatest width of the phragmacone is 55 mm., but 10 mm. farther up the width of the living chamber is 1 mm. greater. The smallest septum, at the base of the specimen, has an estimated width of 25 mm.; from this point the conch widens along the entire length of the phragmacone. The living chamber narrows to 40 mm. at the aperture. The general aspect, viewed from the ventral side, is subfusiform. The conch is depressed dorso-ventrally. At the top of the phragmacone the ratio of the lateral to the dorso-ventral diameter is 55 to 50 mm. Toward the lower end of the phragmacone the cross-section becomes more nearly circular.

The lengthwise curvature of the ventral side of the conch is convex, with a radius of 105 mm. The lengthwise concave curvature of most of the dorsal side of the phragmacone has a radius of 90 mm., until within a short distance of the base of the living chamber. At this upper level the general aspect of the shell is tumid or swollen, the dorsal outline changing from concave to slightly convex. In a general way, this convexity of outline extends from the base of the third camera beneath the living chamber to mid-height of the latter, above which the dorsal outline is slightly concave again. The contraction of the living chamber, both laterally and dorso-ventrally, is quite regular as far as the aperture, with a very faint decrease in the rate of contraction within 5 mm. of the margin of this aperture, in the type, but not in other specimens of this species.

Septa with a concavity of 10 mm. occur at a point where the width of the conch, not the type, is 54 mm. The sutures of the septa appear to be nearly straight on the dorsal and lateral sides, but incline slightly downward toward the ventral side. If there is a tendency toward a slightly concave curvature of the sutures on the ventral side, this is not known definitely, although suspected from the inclination of the three septa seen on the ventral side of the type, where part of the shell has spalled off. In analogy with the species originally described as *Cyrtoceras laterale*, the siphuncle is located on the ventral side of the conch, about 3 mm. distant from the ventral wall.

The surface of the shell is crossed by low, broad, transverse bands or lines of elevation of which 12 occur in a length of 20 mm. These bands are deflected downward on the ventral side of the more inflated part of the conch for a distance of 3 mm.

and for a width of 25 mm., thus locating the hyponomic sinus at earlier stages of growth. A partially exfoliated conch, numbered 3195 at the Public Museum of Milwaukee, Wisconsin, displays vertical bands and striae in addition to the transverse bands.

*Location and horizon.*—In the original description of the species, Racine is mentioned first as a source of material, but the type is from Waukesha, Wisconsin. It is numbered 2112 in the American Museum of Natural History.

*Remarks.*—In the 20th Report of the New York State Cabinet of Natural History, cited above, the generic reference of this species is changed from *Cyrtoceras* to *Oncoceras*, but the type of the latter is a Trenton form, compressed laterally, not depressed dorso-ventrally as in the Racine species here described. Moreover, the segments of its siphuncle are rather narrowly fusiform, instead of cylindrical or barrel-shaped in outline.

Numerous specimens of *Amphicyrtoceras orcas* are in the Greene Museum at Milwaukee-Downer College, in Milwaukee, Wisconsin.

#### 47. AMPHICYRTOCERAS LATERALE (HALL)

PLATE XXX, FIGS. 1 A-D, 2 A, B

*Cyrtoceras laterale* Hall; 20th Rep. New York State Cab. Nat. Hist., 1868, p. 357, pl. 18, figs. 4, 5, 6

*Type.*—*Cyrtoceracone* comparatively little curved. The lengthwise dorsal outline is nearly straight. The corresponding ventral outline is curved lengthwise with a radius of 150 mm. The specimen consists of a phragmacone, with only the basal part of the living chamber still attached. The lateral diameter of the phragmacone increases rapidly from 17 mm. at the base to 37 mm. at the top of the eighth camera from the smaller end. From this point upward, for a distance of 4 camerae, the lateral diameter remains about the same. The contraction near the base of the living chamber is slight. At the smaller end of the phragmacone the transverse section is nearly circular, the dorso-ventral diameter being 17 mm. Farther up, the conch rapidly becomes depressed dorso-ventrally. At the top of the eighth camera, the cross-section is transversely elliptical, the dorso-ventral diameter being 28 mm. The curvature of the conch in a lat-

eral direction is slightly greater on the ventral than on the dorsal side.

The sutures of the septa curve slightly downward along the median parts of the ventral side, especially near mid-length of the phragmacone. The location of the siphuncle at the smaller end of the specimen is indicated by a small circle, 1.5 mm. in diameter, with its center 3 mm. from the ventral wall of the conch. Very faint, low, broad, almost obsolete vertical ribs, about 7 in a width of 20 mm., are seen on casts of the interior of the conch.

*Locality and horizon.*—From Racine, Wisconsin, in the Racine member of the Niagaran. Specimen numbered 2119 in the American Museum of Natural History.

*Milwaukee Museum specimen.*—Another specimen, numbered 634 in the Public Museum of Milwaukee, Wisconsin, consists of the living chamber and 6 upper camerae. The maximum width, 49 mm., occurs at the first camera beneath the living chamber. The contraction of the upper part of the living chamber begins 8 mm. above the base of the latter. The height of this living chamber is 44 mm. It contracts from a width of 49 mm. at its base to an estimated width of 39 mm. at its top. The corresponding dorso-ventral contraction is estimated from 44 mm. at its base to 35 mm. at its top. The phragmacone is distinctly, though gently, concave along its dorsal lengthwise outline. The sutures of the upper septa slant slightly downward toward the ventral side, and curve more strongly downward along the median part of the latter, for a vertical distance of 3 or 4 mm. and for a width of 25 mm. Farther down, the curvature of the sutures becomes less conspicuous. The siphuncle is situated about 3 mm. from the ventral wall of the conch. Its segments are somewhere between short cylindrical and barrel-shaped in vertical outline. At the uppermost camera its diameter is almost 6 mm., diminishing at its passage through the septum to 3 mm. The septal necks are short, about half a millimeter in length. The cast of the interior of the phragmacone is marked by nearly obsolete vertical ribs, extending upward along the lower half of the living chamber, but becoming very indistinct there.

*Remarks.*—*Amphicyrtoceras laterale* evidently is closely related to *Amphicyrtoceras orcas*, and there is a possibility of their being specifically identical. At present, the vertical ribbing of

the casts of the interior of *Amphicyrtoceras laterale*, and a difference in the vertical outline of the upper part of the ventral side of the living chamber, appear characteristic.

48. AMPHICYRTOCERAS TANTALUM SP. NOV.

PLATE XXIX, FIGS. 2 A, B, C

Conch small, with its maximum lateral diameter, 27.5 mm., along the second camera beneath the living chamber. Above this point the lateral diameter shortens, at first slowly and then more rapidly for a height of 15 mm., where its lateral diameter is 19 mm. Above this the conch rises at least 8 mm. as a narrow neck, terminating in the specimen at hand at about the level of the aperture. The rate of enlargement of the lower part of the phragmacone is rapid. The conch is strongly depressed dorso-ventrally, the ratio of the dorso-ventral to the lateral diameter being as 24 to 27.5 mm. at the widest part of the conch. At the aperture the corresponding ratio is as 15.5 to 19 mm. At the base of the specimen it is as 14 to 16 mm. A little over 8 camerae occur in a length equal to the maximum width of the conch. The sutures are nearly directly transverse, but sag down a little on the ventral side of the conch. The septa are very moderately concave, and the siphuncle appears to occur one-third of the dorso-ventral diameter from the ventral side. Its passage through the septum at the base of the specimen is small, and the form and structure of its segments are unknown.

*Locality and horizon.*—From the strata regarded as approximately equivalent to the Cedarville dolomite, at the abandoned railroad quarry in the northeastern part of Hillsboro, Ohio. Found by Henry Pavey.

*Remarks.*—*Amphicyrtoceras tantalum* is characterized by its small size, the rapid constriction of the living chamber, and the elongation of the upper part of this chamber into a neck.

MONOCYRTOCERAS GEN. NOV.

Genotype: *Monocyrtoceras lentidilatatum* Foerste

Conch related to *Amphicyrtoceras*, but enlarging at a much smaller rate; there is no dorsal gibbosity; and the siphuncle is much nearer the center of the conch, being only a short distance ventrad of the latter.

## 49. MONOCYRTOCERAS LENTIDILATATUM SP. NOV.

PLATE XXXVII, FIG. 1; PLATE XXXVIII, FIG. 1; PLATE XXXIX, FIG. 1; PLATE XL, FIGS. 1A, B; PLATE XLI, FIGS. 3A, B

*Greenfield specimen.*—Specimen consisting of the lower part of a living chamber with 11 camerae still attached. A twelfth camera is represented by the cast of the interior of one of the segments of the siphuncle, at the base of the specimen. Conch distinctly curved lengthwise, the radius of curvature of the convex or ventral side being about 450 mm., and that of the concave or dorsal side about the same. The conch is distinctly compressed dorso-ventrally. The dorso-ventral diameter at the base of the living chamber is 66 mm., the lateral diameter being estimated at 75 mm. The lateral diameter enlarges from 60 mm. at the base of the specimen to 75 mm. at the base of the living chamber, the intervening distance being 125 mm., measured along the ventral side of the conch, but most of this enlargement takes place along the lower 5 camerae retained by the specimen. The living chamber contracts slightly laterally, in an upward direction. The dorso-ventral diameter increases from 53 mm. at the base to 60 mm., 5 camerae farther up, and to 66 mm. at the base of the living chamber. Apparently it continues to enlarge for 40 mm. above the suture outlining the base of the living chamber. About 6 camerae occur at the top of the phragmacone in a length equal to the lateral diameter of the conch, but the uppermost two camerae shorten rapidly, indicating that the specimen was fully mature. In descending order, the uppermost camera has a length of 6 mm., the next beneath of 8 mm., and the next 7 or 8 camerae of 10 or 11 mm.

The sutures of the septa curve downward moderately both dorsally and ventrally, and rise laterally to a corresponding degree. The concavity of the septum at the base of the specimen equals 13 mm. When the dorso-ventral diameter is 53 mm., the center of the siphuncle is 21 mm., or two-fifths of the dorso-ventral diameter, from the ventral wall of the conch. The lateral diameter of the siphuncle, where in contact with the septum beneath, is 13 mm., and it contracts here suddenly to 7 mm. at the beginning of the septal neck. The lower margin of this neck flares out strongly, the length of the neck being slightly over 1 mm. The sides of the segments of the siphuncle, within the walls of the camerae, present straight profiles, the segments hav-

ing the form of tubes connected by short central passages of much smaller diameter. In form, the siphuncle closely resembles that of *Amphicyrtoceras orcas* (Hall), from the Racine of Wisconsin, but the conch is much more elongate.

The surface of the shell is crossed by transverse, and rather faint, raised lines or striae. The surface of the cast of the interior of the specimen is faintly ribbed vertically, as in some specimens of *Amphicyrtoceras orcas*.

*Locality and horizon.*—Greenfield, Wisconsin; in the Racine member of the Niagaran. No. 2315, in the Museum of Comparative Zoology, at Harvard University.

*Living chambers from Wauwatosa.*—With the specimen described above, consisting chiefly of the phragmacone, are correlated two living chambers, found at another locality. These living chambers agree fairly well in size and cross-section with the remnant of the living chamber preserved in the preceding specimen. Moreover, these living chambers are of such length, and have such a slow rate of contraction toward the aperture as to suggest that they belong to a slowly enlarging species, and *Amphicyrtoceras lentidilatatum* is such a species.

At the base of one of the living chambers, the dorso-ventral diameter is 70 mm., and the lateral diameter is 78 mm. Along the dorsal side of the living chamber, the margin of the aperture rises 78 mm. above the suture at its base. Here the lateral diameter is 69 mm., and the dorso-ventral diameter is estimated at 63 mm. Distinct contraction of the living chamber begins about 30 to 35 mm. above its base. At the base of the cast of the interior, there is a transverse groove 6 mm. high, locating the annular attachment ring following the inner wall of the chamber. This groove is crossed by 10 low vertical ribs in a width of 35 mm., their upward continuations being faintly visible for some distance above the transverse groove. Laterally this groove makes an angle of  $10^{\circ}$  with a horizontal plane, sloping from the dorsal side downward toward the ventral. The margin of the aperture forms a broad shallow lobe on the ventral side; it rises laterally and ventro-laterally, and curves distinctly, though only moderately, downward along the median part of the ventral side, thus locating the hyponomic sinus. Toward the upper part of the living chamber, the median part of the ventral side extends slightly outward beyond the general trans-

verse curvature of the conch, but so slight is this outward curvature that it is likely to escape attention. An accentuation of this outward curvature would lead to forms such as those included under *Streptoceras*. Within 5 or 10 mm. from the aperture the dorsal and ventral walls of the cast of the interior of the living chamber curve slightly outward. The surface of the shell is striated faintly in a transverse direction, and weathered parts of the surface show very faint vertical striae.

*Location and horizon*.—Schoonmaker's quarry, at Wauwatosa, Wisconsin, in the Racine member of the Niagaran. No. 2312, in the Museum of Comparative Zoology, at Harvard University.

*Flattened Wauwatosa phragmacone*.—The specimen consists of 15 camerae, no part of the living chamber being retained. It is of interest chiefly because it gives some idea of the rate of increase in the size of the conch, notwithstanding the fact that it is strongly compressed dorso-ventrally, evidently during fossilization. This flattening probably is due to vertical compression of the enclosing strata. There is no evidence that the width of the specimen was increased by this flattening. The height of the camerae agrees very well with that of the camerae in the type specimen from Greenfield, Wisconsin.

Specimen No. 2301, in the Museum of Comparative Zoology, at Harvard University. From Wauwatosa, Wisconsin.

#### 50. DIESTOCERAS GEN. NOV.

Genotype: *Gomphoceras indianense* Miller and Faber

Conch relatively erect, practically without any lengthwise curvature, though possibly gently curved in its initial stages of growth. There is only a slight difference in the lengthwise curvature of the dorsal and ventral sides of the upper part of the conch. The siphuncle is located close to the ventral wall, and the segments are so low and broad as to appear nummuloidal. The walls of the living chamber converge toward the aperture, but the latter is much less contracted than in *Gomphoceras*. On the contrary, the aperture remains relatively wide open, with only a moderate angularity on the ventral side, along the hyponomic sinus. The hyponomic sinus is relatively shallow and does not form a lobe distinct from the remainder of the aperture.

*Gomphoceras indianense* Miller and Faber is selected as the genotype, because this species is by far the most abundant, at

least in southwestern Ohio. *Gomphoceras eos* and *Gomphoceras obesum* are congeneric. *Poterioceras apertum* Whiteaves, *P. nobile* Whiteaves, and possibly *P. gracile* Whiteaves, also belong here. *Oncoceras alceus* Hall is another species.

51. **DIESTOCERAS INDIANENSE (MILLER AND FABER)**

PLATE XXV, FIGS. 1A, B; PLATE XXVI, FIGS. 1A, B, 2A, B;  
PLATE XXVII, FIG. 2

*Gomphoceras indianense* Miller and Faber, Jour. Cincinnati Soc.  
Nat. Hist., vol. 17, 1894, p. 137, pl. 7, figs. 3-5

*Type*.—Three specimens were collected by Faber in the upper part of the Richmond at Versailles, Indiana, and one was figured. The siphuncle was described as marginal, located on the ventral side of the conch, and abruptly expanded within the camerae to two and a half or three times its diameter at the septa.

*Oxford specimens*.—Conch (Plate XXV, Figs. 1A, B) relatively short, rapidly expanding along the lower part of the phragmacone, attaining its largest diameter at the base of the living chamber, distinctly contracting toward the aperture. In specimens retaining about 10 of the upper camerae of the phragmacone, the total length of these camerae along the dorsal side of the conch is a little greater than their total length along the ventral side, and the sutures of the septa rise slightly higher along the dorsal side, especially toward the living chamber. The vertical axis of the conch is nearly straight, but there is a faint tendency toward a lengthwise concave curvature along the ventral side. From this it is assumed that the location of the siphuncle is endogastric. The conch is slightly compressed laterally. In the specimen which seems least flattened by lateral pressure, the dorso-ventral diameter at the base of the living chamber is 63 mm., and the lateral diameter is 58 mm. At the base of the specimen, 46 mm. farther down, the cross-section is virtually circular, and about 34 mm. in diameter. Two very short camerae at the top of the phragmacone indicate that this specimen had reached full maturity. The living chamber is 38 mm. in height. The margin of the aperture is nearly directly transverse on its dorsal and lateral sides, but curves distinctly downward ventrally, forming a relatively shallow V-shaped hyponomic sinus. Possibly the margin of this aperture inclines slightly downward toward the dorsal side also, but this cannot be determined definitely from the specimen at hand. The lateral diameter of the

aperture is 39 mm.; its dorso-ventral diameter may be slightly greater. Its general form is circular, but along its ventral margin it is distinctly angular, though the angularity still is rounded. The margin of the aperture curves more or less horizontally inward for a distance of 3 or 4 mm.; perhaps less toward the ventral angularity. At this angularity the margin of the aperture curves downward, forming the hyponomic sinus.

In a second specimen, (Plate XXVI, Figs. 1A, B) from the same locality and horizon, the specimen is more compressed laterally, probably by pressure during fossilization. The lengthwise ventral outline is more convex. The aperture is well exposed, including the hyponomic sinus, but it also is compressed laterally.

The surface of casts of the interior of the conch usually is faintly ribbed vertically along the phragmacone. The surface of the shell is crossed transversely by low broad lines of elevation of variable strength, representing successive stages of growth. These serve to locate the ventral side of the conch, where they curve distinctly downward.

At the base of the eighth camera below the living chamber of one specimen, where in the present flattened condition of the specimen the diameters at right angles to each other are 42 and 37 mm., the maximum diameter of the siphuncle is 8.5 mm. and its passage through the septum is 5.5 mm. in diameter. At its contact with the overlying septum, the exposed segment of the siphuncle is in contact with the latter over its entire width, forming a circular area of contact, which is penetrated by the passage of the siphuncle through the septum in a strongly eccentric position, its ventral margin being less than 1 mm. from the ventral margin of the segment. The ventral side of the segment is curved obliquely, in a direction approximately parallel to the ventral wall of the conch.

*Locality and horizon.*—Little Four Mile creek, near Oxford, Ohio; in the lower part of the Whitewater member of the Richmond formation. In the collection of Prof. W. H. Shideler, at Miami University.

*Faber specimen.*—A vertical section, in a dorso-ventral direction, through a specimen (Plate XXVI, Figs. 2A, B) collected by Mr. C. L. Faber at the same horizon on Little Four Mile creek, exposes the siphuncle sufficiently to indicate its relative

size, and the convexity of the vertical outlines of its segments; but the siphuncle has broken loose from the septa, and the structure of the siphuncle can not be determined in a satisfactory manner.

*Saluda and Elkhorn specimens.*—Specimens from the Saluda and Elkhorn members of the Richmond are in the collection of Prof. W. H. Shideler. These specimens evidently are congeneric with *Diestoceras indianense*, but not enough of the conch is preserved to make certain that they belong to the same species. One of these Saluda specimens (Plate XXVII, Fig. 2) preserves the surface striae very well.

52. *DIESTOCERAS EOS* (HALL AND WHITFIELD)

PLATE XXVIII, FIGS. 1A, B

*Gomphoceras eos* Hall and Whitfield; Geol. Surv. Ohio, Pal., vol. 2, 1875, p. 100, pl. 3, fig. 5

\**Type.*—Specimen 112 mm. in length; of this length 65 mm. belongs to the living chamber, 36 mm. belong to that part of the phragmacone which occurs between the base of the living chamber and the suture of the septum at the base of the specimen, and 11 mm. belongs to that part of the specimen which extends below the level of this suture in consequence of the downward curvature of the septum.

In its present condition the specimen is very much crushed laterally. The maximum expansion of the conch takes place about 23 mm. above the base of the living chamber. Here the dorso-ventral diameter is 81 mm., and the lateral diameter is 36 mm. At the base of the living chamber the corresponding diameters are 74 and 30 mm. At the base of the specimen these diameters are 44 mm. and 19 mm. The apical angle of that part of the phragmacone which is preserved approximates  $45^{\circ}$ . Above mid-height of the living chamber the latter contracts so that at 55 mm. above its base the dorso-ventral diameter is 62 mm. and the lateral diameter 21 mm. Above this level the living chamber continues to contract until its dorso-ventral diameter does not exceed 55 mm.

It is assumed, from the better preserved specimens of *Diestoceras indianense*, that the cross-section of *Diestoceras eos* originally was nearly circular, and that the outline of the aperture was nearly circular, with a moderate amount of angularity along the ventral margin. In conformity with other species referred

to *Diestoceras*, the side along which the septa are more approximate is regarded as ventral, while that along which they are more distant from each other is regarded as dorsal. Along the ventral side of the specimen 7 camerae occupy a length of 36 mm., while along the dorsal side the same 7 camerae occupy a length of 46 mm. The sutures of the septa rise slightly from the ventral toward the dorsal side of the conch. They are approximately straight. The septa may have been more deeply concave than in *Diestoceras indianense*, but the exposed septum at the base of the specimen may have secured its present form from crushing. No trace of the siphuncle is retained.

*Locality and horizon.*—From the vicinity of Dayton, Ohio, at the base of the Whitewater member of the Richmond formation. Specimen No. 3082, in the Geological Museum of Ohio State University. Along its upper margin the specimen contains a ventral valve of *Rhynchotrema capax*. Traces of an incrusting bryozoan occur on one side of the specimen.

*Remarks.*—*Diestoceras eos* differs from typical *Diestoceras indianense* in attaining the maximum enlargement of the conch at a point distinctly above the base of the living chamber. It is possible that the two species are identical, but, without a greater number of specimens at hand, it is not known within what limits *Diestoceras indianense* varies. The type of *Diestoceras eos* is so badly flattened as to leave elements of uncertainty, while that of *Diestoceras indianense* is much less distorted, and this species can be identified with confidence. For the present, at least, the latter is described as distinct.

53. *DIESTOCERAS SHIDELERI* SP. NOV.

PLATE XXVII, FIGS. 1A, B

Specimen presenting an elongate elliptical outline, consisting chiefly of a living chamber 55 to 58 mm. in height, with 4 camerae attached at its base. The specimen reaches its greatest transverse dimensions at mid-height of the living chamber. Here its lateral diameter is 67 mm., and its dorso-ventral diameter is 63.5 mm. At the base of the living chamber the corresponding diameters are 64 and 61 mm. respectively. At 50 mm. above the base of the living chamber the lateral walls curve strongly inward and then upward. Possibly this change in curvature indicates merely a thickened border in the interior of the chamber,

strengthening the margin of the aperture. Along the ventral side this margin appears to curve downward, forming a distinct hyponomic sinus.

The upper part of the phragmacone narrows so rapidly in an apicad direction that it is probable that the phragmacone was very short. The sutures of the septa rise distinctly from the ventral toward the dorsal side of the conch, and the height of the camerae enlarges in this direction. The siphuncle is exposed close to the ventral side of the conch. Within the lowest camera its diameter was at least 14 mm. The location of the passage of the siphuncle through the septum evidently was similar to that in *Diestoceras indianense*.

#### 54. CYRTOGOMPHOCERAS GEN. NOV.

Genotype: *Oncoceras magnum* Whiteaves. Trans. Royal Soc. Canada, vol. 7, sec. 4, 1890, p. 79, pl. 15, fig. 1

Conch distinctly curved lengthwise, endogastric, and laterally compressed. The dorsal side is strongly convex, and the ventral outline of all but the uppermost part of the phragmacone is slightly concave, but along the top of the phragmacone and the adjacent part of the living chamber the ventral outline is distinctly gibbous. Conch compressed laterally. Sutures of the septa rising strongly from the ventral toward the dorsal side of the conch along the upper part of the phragmacone. Aperture correspondingly oblique, the living chamber being strongly contracted toward the latter. Siphuncle near the ventral wall of the conch, its segments strongly nummuloidal.

In addition to the genotype, *Oncoceras magnum* Whiteaves, this genus includes also *Oncoceras whiteavesii* Miller, a species originally described by Whiteaves as *Oncoceras gibbosum*.

*Oncoceras intermedium* Whiteaves is similar in having a strongly nummuloidal siphuncle near the concave or ventral side of the conch, and in having the septa rise strongly toward the dorsal side, but the conch is more slender, there is no gibbosity along the ventral side of the conch, and there is no evidence at present of the living chamber having a structure similar to that of typical *Cyrtogomphoceras*.

## PLATE XXI

Fig. 1. *Endoceras proteiforme* Hall. Ventral side of the conch, showing downward flexure of the sutures of the septa, the siphuncle, and traces of the endocones, both at the top and near the middle of the specimen. Same specimen as fig. 4 on pl. 48 of Pal. New York, vol. 1, 1847. See also plate XXII, figs. 1A, 1B. Selected here as type of the species.

Fig. 2. *Endoceras proteiforme* Hall. Ventral side of a specimen, showing the downward curvature of the sutures of the septa, and the concave vertical outline of the septal necks of the siphuncle. Same specimen as fig. 1a on plate 49 of Pal. New York, vol. 1, 1847. See also fig 2 on pl. XXII, and fig. 2 on pl. XXIII.

Fig. 3. *Endoceras proteiforme* Hall. Ventral side of a specimen, showing the siphuncle. Same specimen as figs. 1b, 1c on pl. 49 of Pal. New York, vol. 1, 1847. See also figs. 1A, 1B on pl. XXIII.

All specimens figured on this plate are from Middleville, New York, in the Trenton limestone.



1



2



3

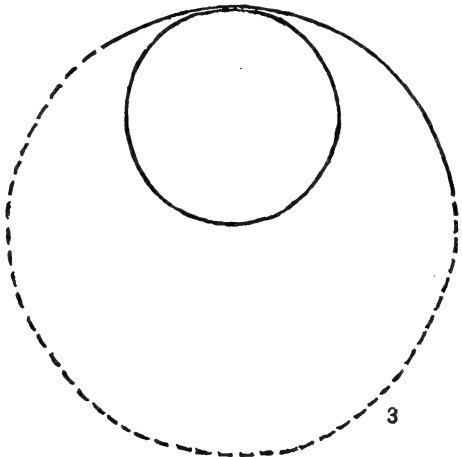
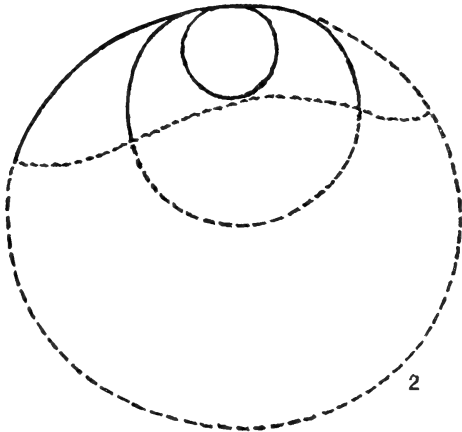
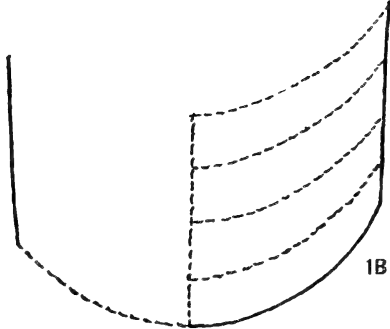
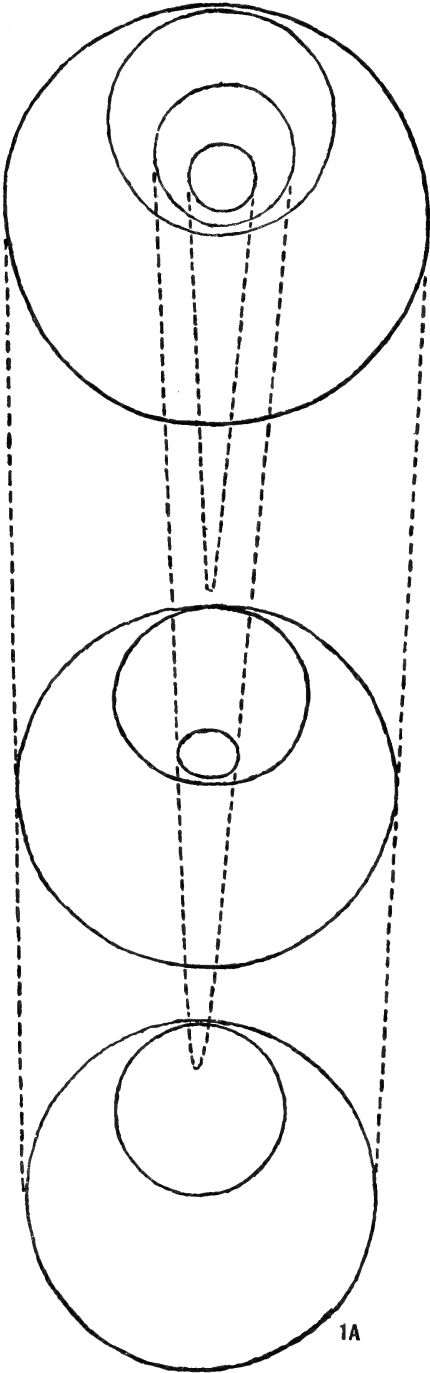
## PLATE XXII

Fig. 1. *Endoceras proteiforme* Hall. A, three transverse sections of the type specimen at intervals corresponding to the distances between the centers of the sections; showing the rate of increase of the conch, siphuncle, and endocones. B, diagrammatic ventro-dorsal vertical section of the same specimen. See also fig. 1 on pl. XXI.

Fig. 2. *Endoceras proteiforme* Hall. Transverse section of same specimen as fig. 2 on pl. XXI, with missing parts indicated by broken lines. See also fig. 2 on pl. XXIII.

Fig. 3. *Endoceras proteiforme* Hall. Transverse section of same specimen as fig. 2 on pl. XXV, with missing parts indicated by broken lines. See also fig. 3 on pl. XXIII.

All specimens figured on this plate are from Middleville New York, in the Trenton limestone.



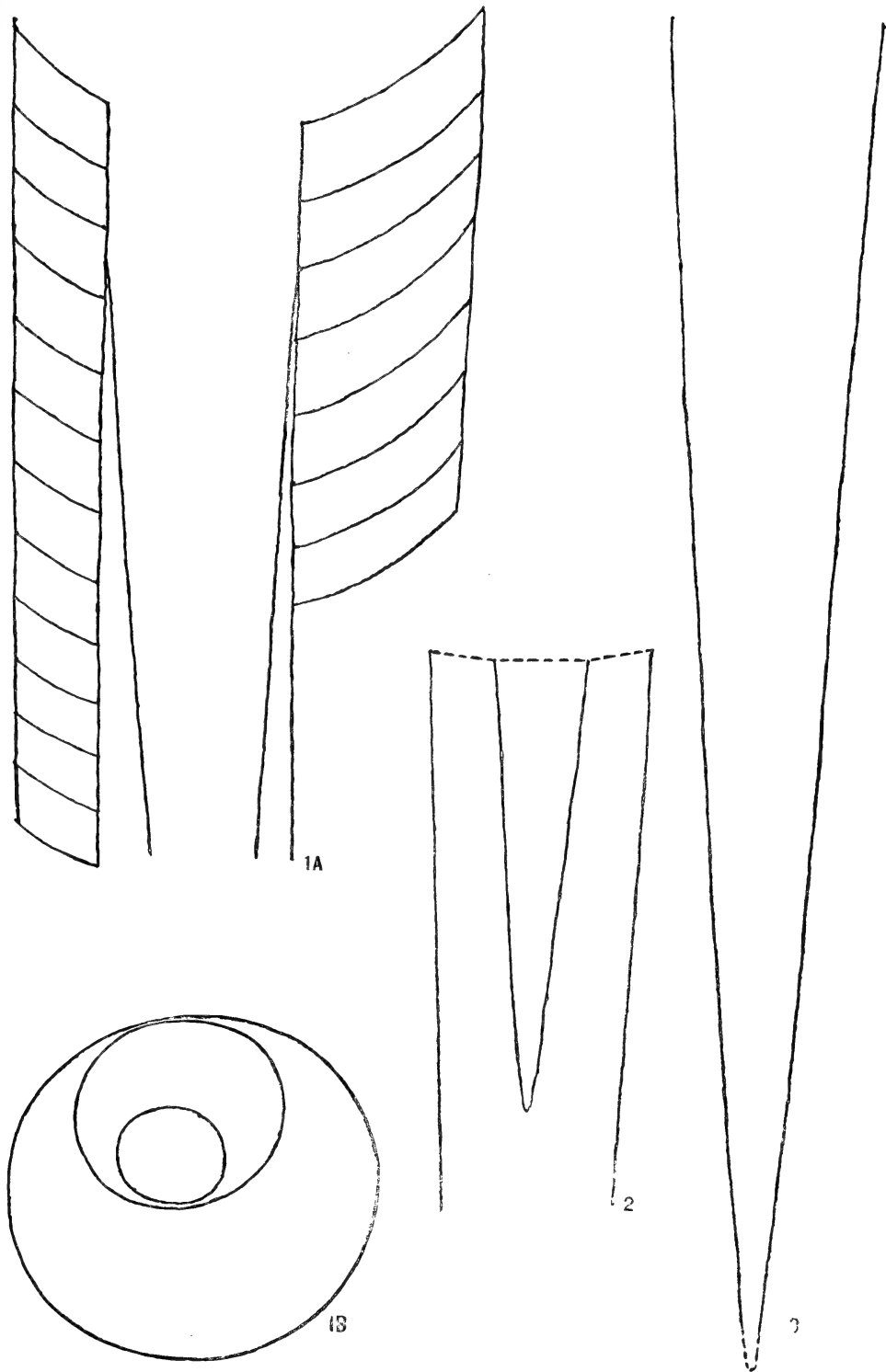
### PLATE XXIII

Fig. 1. *Endoceras proteiforme* Hall. A, vertical section, showing the upper part of an endocone. B, cross-section showing siphuncle and endocone. Same specimen as fig. 3 on pl. XXI.

Fig. 2. *Endoceras proteiforme* Hall. Vertical section through the siphuncle, showing the apical part of an endocone. Same specimen as fig. 2 on pl. XXI, and fig. 2 on pl. XXII.

Fig. 3. *Endoceras proteiforme* Hall. Vertical section of the endocone in fig. 1e of pl. 49 of the Pal. of New York, vol. 1, 1847, to show its rate of taper and its form before it was distorted. See also fig. 2, on pl. XXV, and fig. 3 on pl. XXII.

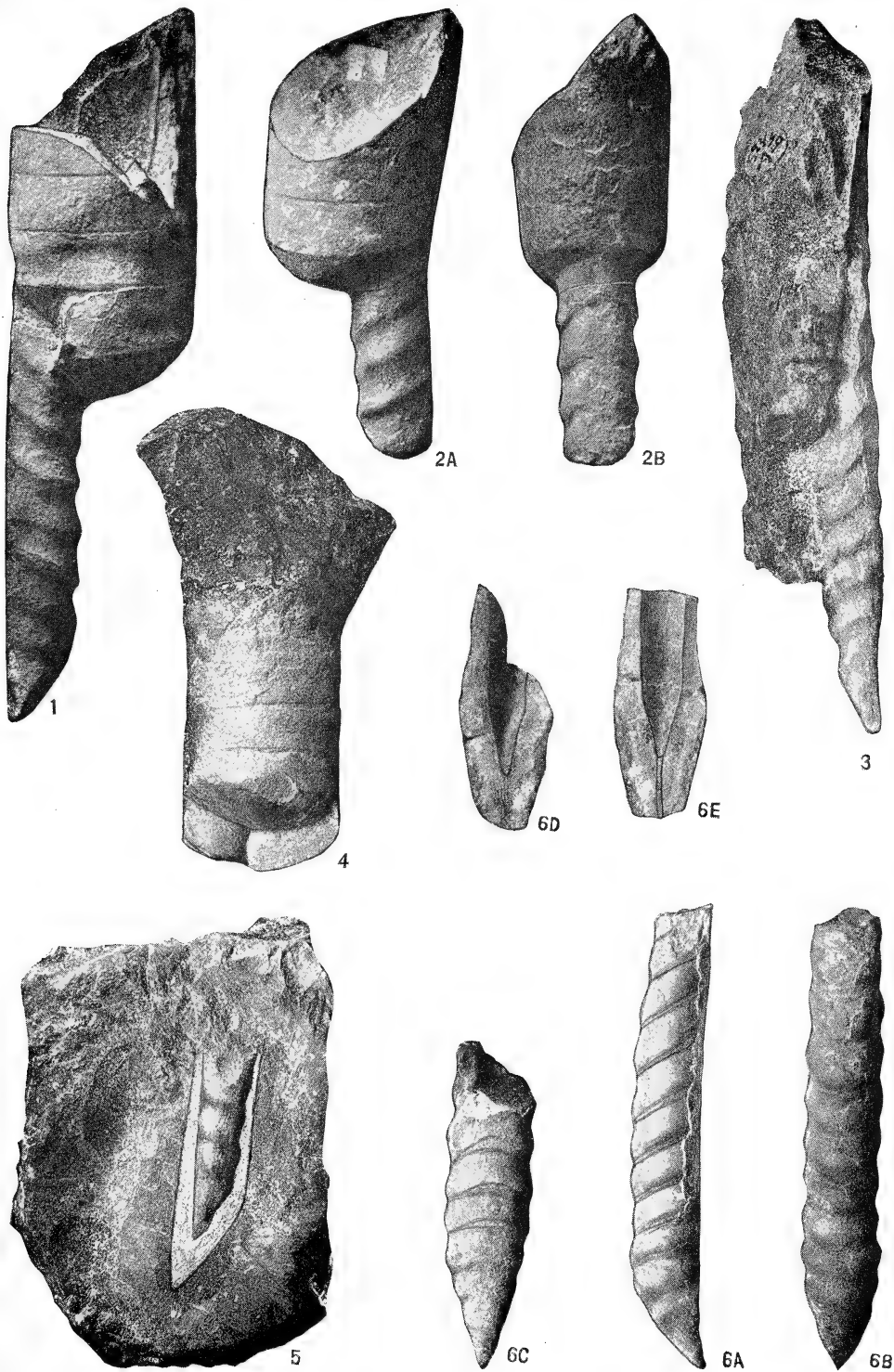
All specimens figured on this plate are from Middleville, New York, in the Trenton limestone.



#### PLATE XXIV

Figs. 1-5. *Cameroceras trentonense* Hall. 1, 2A, lateral views showing siphuncle. 2B, ventral view of 2A. 3, cast of interior of siphuncle and endocone; compare with 5. 4, lateral view, exposing one segment of the siphuncle. 5, endocone, thickened interiorly by a calcareous deposit, lighter in color, contrasting with the darker color of the matrix filling the interior of the endocone. 1, 2, from Middleville, New York; No. 815 in American Museum of Natural History; originals of Pal. New York, vol. 1, 1847, pl. 56, figs. 4 a, b, c. 3, 4, from Multona brook, 2 miles northeast of Middleville, New York; No. 59449, in the U. S. National Museum. 5, from Poland, in Herkimer, New York; No. 59450, in the U. S. National Museum. All specimens from the Trenton limestone.

Figs. 6 A-E. *Cameroceras calumettense* Foerste. A lateral view; B, view of same specimen, facing the interior of the conch. C, ventral side of another specimen. D, E, opposite sides of an endocone split so as to show the thickened inner walls of the endocone, but omitting the deposit of matrix which filled its interior. At the base of the specimen, the axial part of the calcareous deposit is occupied by a thin transverse band, scarcely 1 mm. in width. From Little Calumet creek, 6 miles south of Louisiana, Missouri. In the U. S. National Museum.



## PLATE XXV

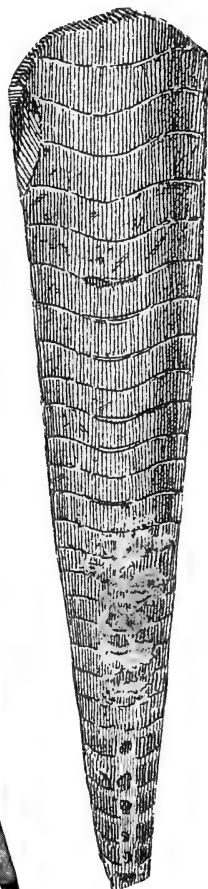
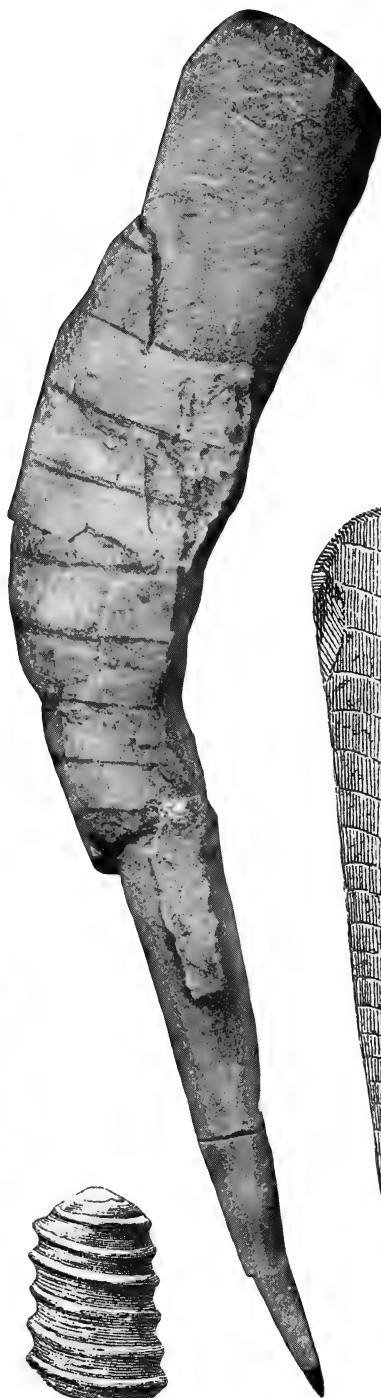
Figs. 1 A, B. *Diestoceras indianense* (Miller and Faber). A, ventral view. B, lateral view of same specimen. From Little Four Mile creek, near Oxford, Ohio; in the lower part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler of Miami University.

Fig. 2. *Endoceras proteiforme* Hall. Lateral view, with ventral side on left. See also Plate XXII, Fig. 3; Plate XXIII, Fig. 3. From Middleville, New York. Same specimen as Fig. 1e on Pl. 49, of the Pal. New York, vol. 1, 1847. In the Trenton limestone.

Fig. 3. *Orthoceras breynii* Martin. Ventral side. Figure copied from *Petrefacta Derbiensis*, 1809, pl. 39, fig. 4. Stated to be frequent in black marble at Ashford. A Carboniferous species.

Fig. 4. *Orthoceras annularis* Fleming. Lateral view, inverted from original. Copied from Fleming, *Ann. Phil.*, pl. 31, Fig. 8. Carboniferous.

Fig. 5. *Orthoceras annulare* Phillips. Lateral view. Copied from Phillips, *Geology of Yorkshire*, 1836, pl. 21, fig. 9. Carboniferous.



#### PLATE XXVI

Figs. 1 A, B. *Diestoceras indianense* (Miller and Faber). A, lateral view. B, ventral view. From Little Four Mile creek, near Oxford, Ohio. Collected by Prof. W. H. Shideler, of Miami University.

Figs. 2 A, B. *Diestoceras indianense* (Miller and Faber). A, vertical dorso-ventral section showing poorly preserved siphuncle. B, same specimen. From Little Four Mile creek, near Oxford, Ohio. Collected recently by C. L. Faber, from the basal part of the Whitewater member of the Richmond formation.



## PLATE XXVII

Figs. 1 A, B. *Diestoceras shideleri* Foerste. A, lateral view with ventral side on right. B, ventral view, with siphuncle at base. From the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.

Fig. 2. *Diestoceras* cf. *indianense* (Miller and Faber). View showing the surface striae. From the Saluda member of the Richmond. Collected by Prof. W. H. Shideler.

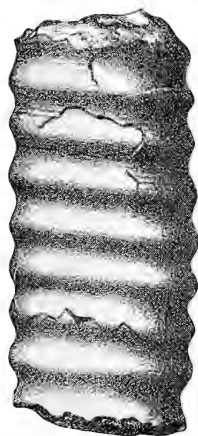
Figs. 3 A, B. *Perigrammoceras laevigatum* (McCoy). A, partly exfoliated conch, with surface of shell showing transverse striae. B, part of specimen enlarged, showing surface striae. Copied from Foord, Carb. Ceph. Ireland, 1897, pl. 5, figs. 1d, 1e. Of Carboniferous age.



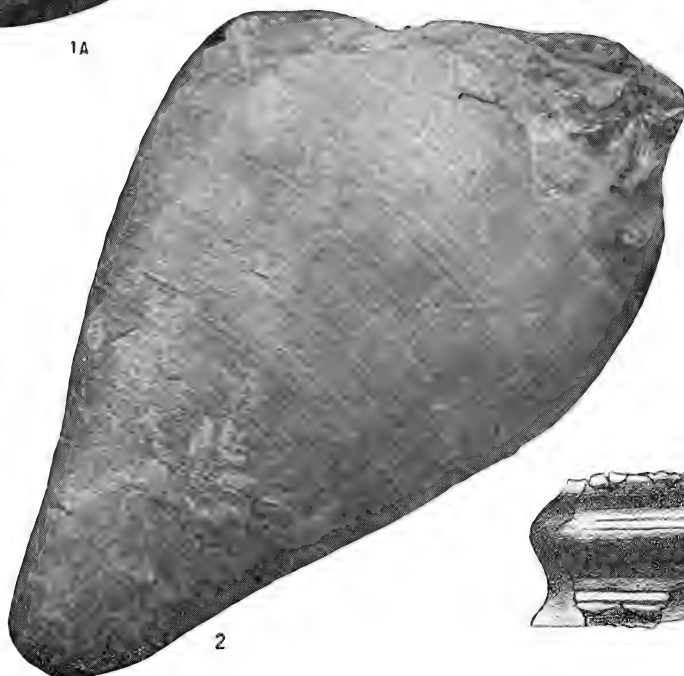
1A



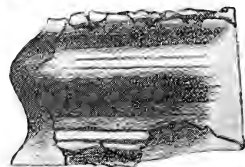
1B



3A



2



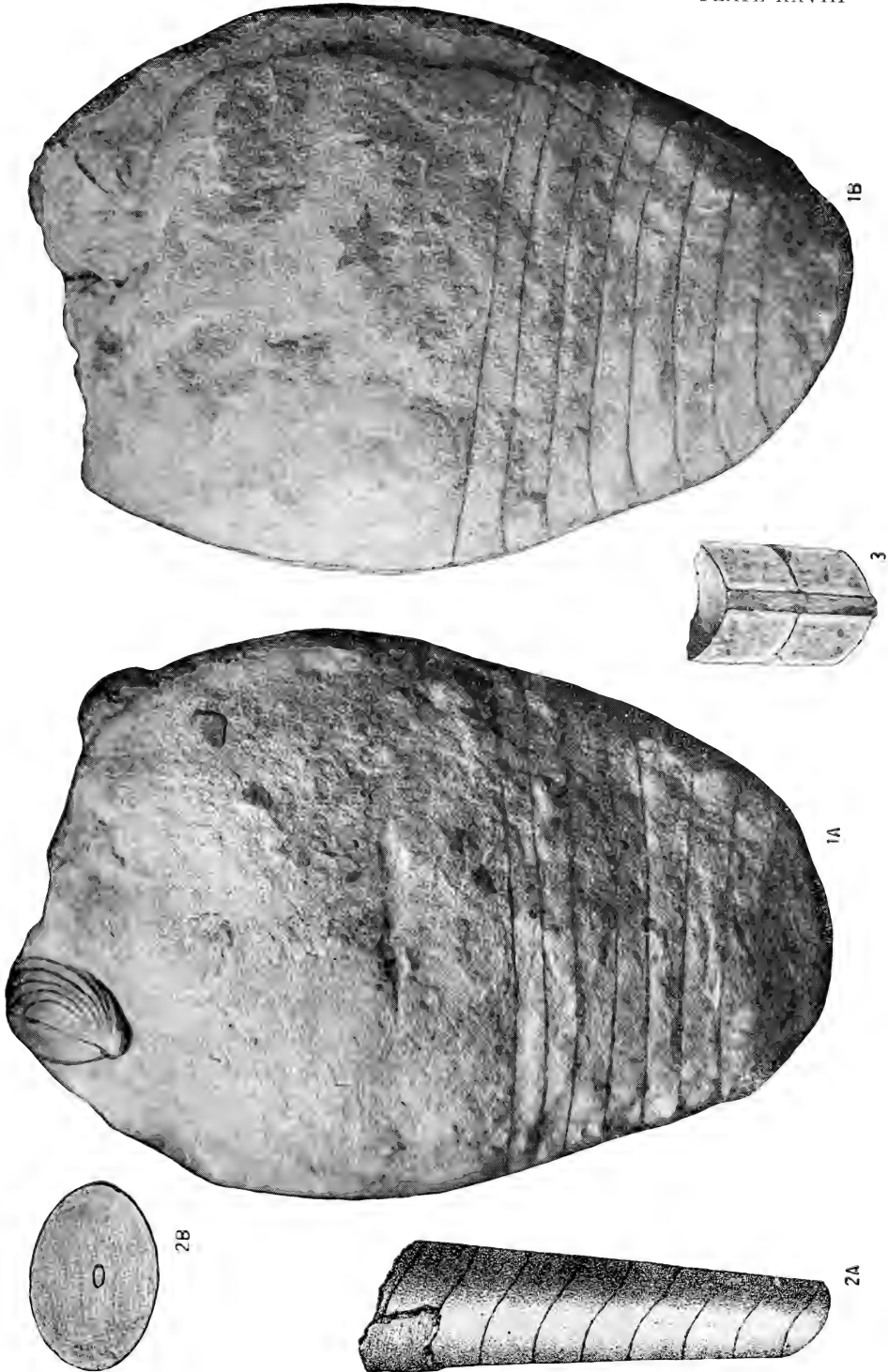
3B

### PLATE XXVIII

Figs. 1 A, B. *Diestoceras eos* (Hall and Whitfield). Opposite sides of the same specimen. Ventral side assumed to be near left side of A, and right side of B. From vicinity of Dayton, Ohio, assumed to be from basal part of Whitewater member of Richmond. Type, numbered 3082, in the Geological Museum of Ohio State University. Same specimen as that figured in Ohio Pal., 2, 1875, pl. 3, fig. 5.

Figs. 2 A, B. *Loxoceras distans* McCoy. A, lateral view with ventral side on right. B, cross-section, with lateral diameter larger. Copied from McCoy, Carb. Foss. Ireland, 1844, pl. 4, fig. 1. From the Carboniferous.

Fig. 3. *Lituities* sp. Vertical section through a fragment, from a large series of specimens from Esthonia, in the U. S. National Museum.



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#### PLATE XXIX

Figs. 1 A, B, C. *Amphicyrtoceras orcas* (Hall). A, ventral view. B, lateral view showing the septa. C, two cross-sections, one taken at the base of the living chamber, the other 5 camerae lower. From Waukesha, Wisconsin; in the Racine member of the Niagaran. Type, numbered 2112, in the American Museum of Natural History. Same specimen as in 20th Rep. New York State Mus. Nat. Hist., 1868, pl. 17, figs. 1, 2.

Figs. 2 A, B, C. *Amphicyrtoceras tantalum* Foerste. A, ventral view. B, lateral view. C, two cross-sections, one at base of living chamber, the other at base of specimen. From railroad quarry in northeastern edge of Hillsboro, Ohio; from the Cedarville member of the Niagaran.

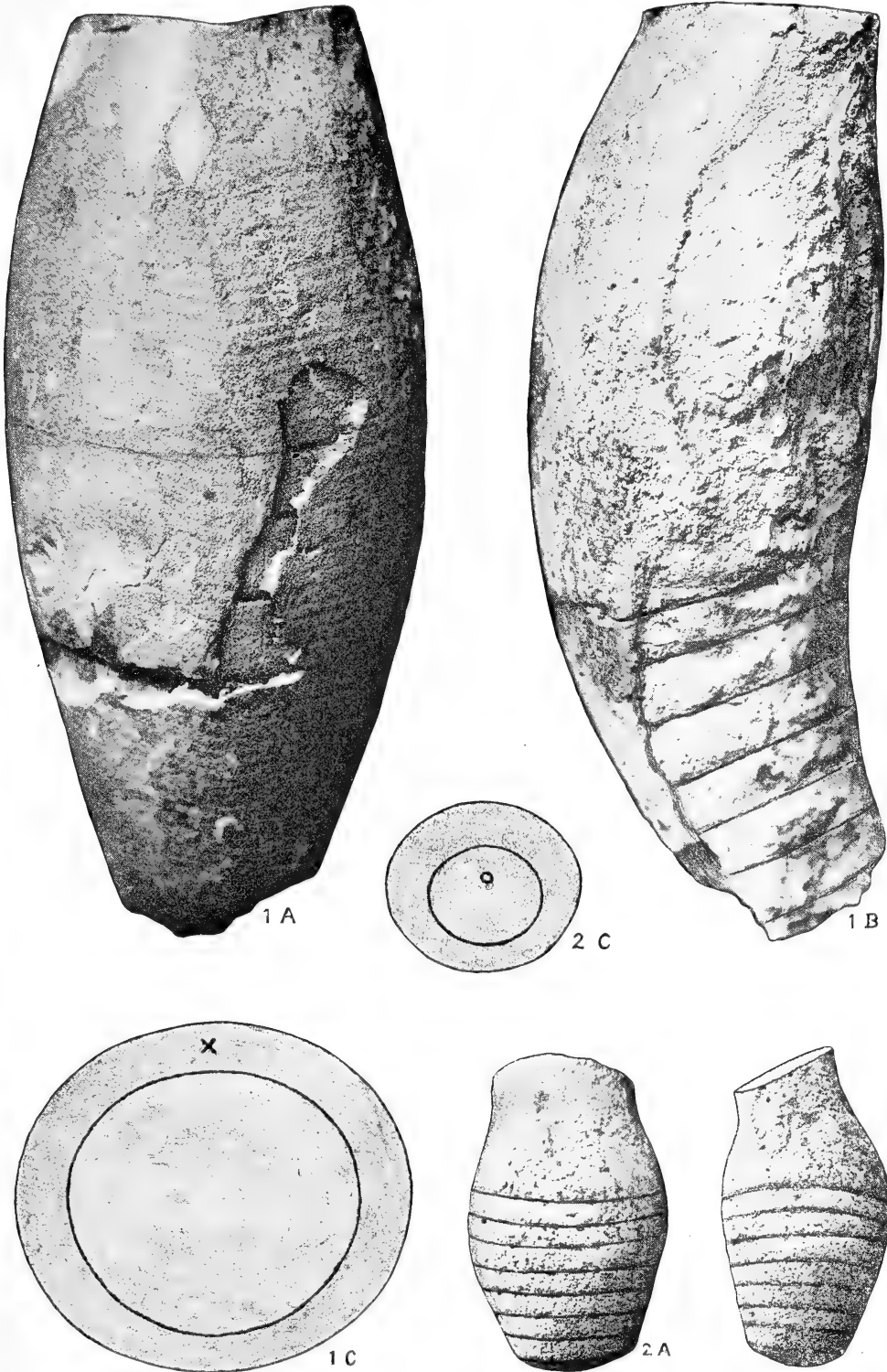
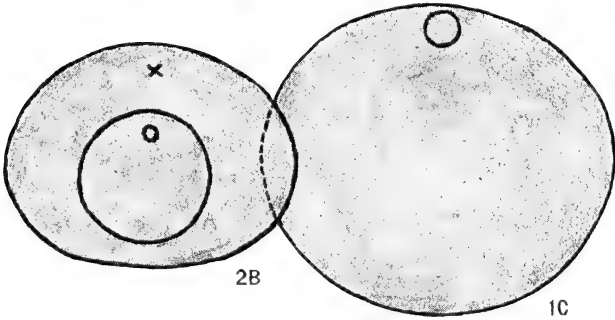


PLATE XXX

Figs. 1 A, B, C, D. *Amphicyrtoceras laterale* (Hall). A, dorsal view. B, lateral view. C, cross-section at base of the living chamber. D, vertical dorso-ventral section, exposing the siphuncle, taken at top of phragmacone. From Racine member of Niagaran at some Wisconsin locality. No. 634, in the Public Museum of Milwaukee, Wisconsin.

Figs. 2 A, B. *Amphicyrtoceras laterale* (Hall). A, ventral view. B, two cross-sections, one at base of living chamber, the other at base of specimen. From Racine, Wisconsin, in the Racine member of the Niagaran. Type, numbered 2119, in the American Museum of Natural History. Same specimen as that figured in 20th Rep. New York State Museum Nat. Hist., 1868, pl. 18, figs. 4, 5, 6.



1C

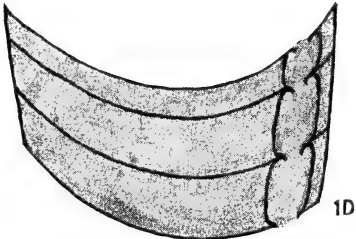
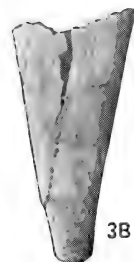
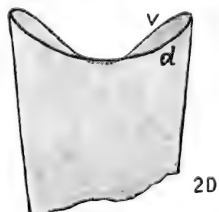
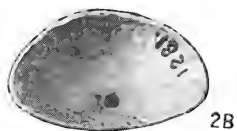
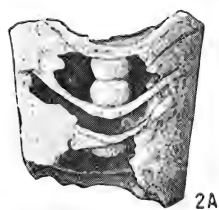
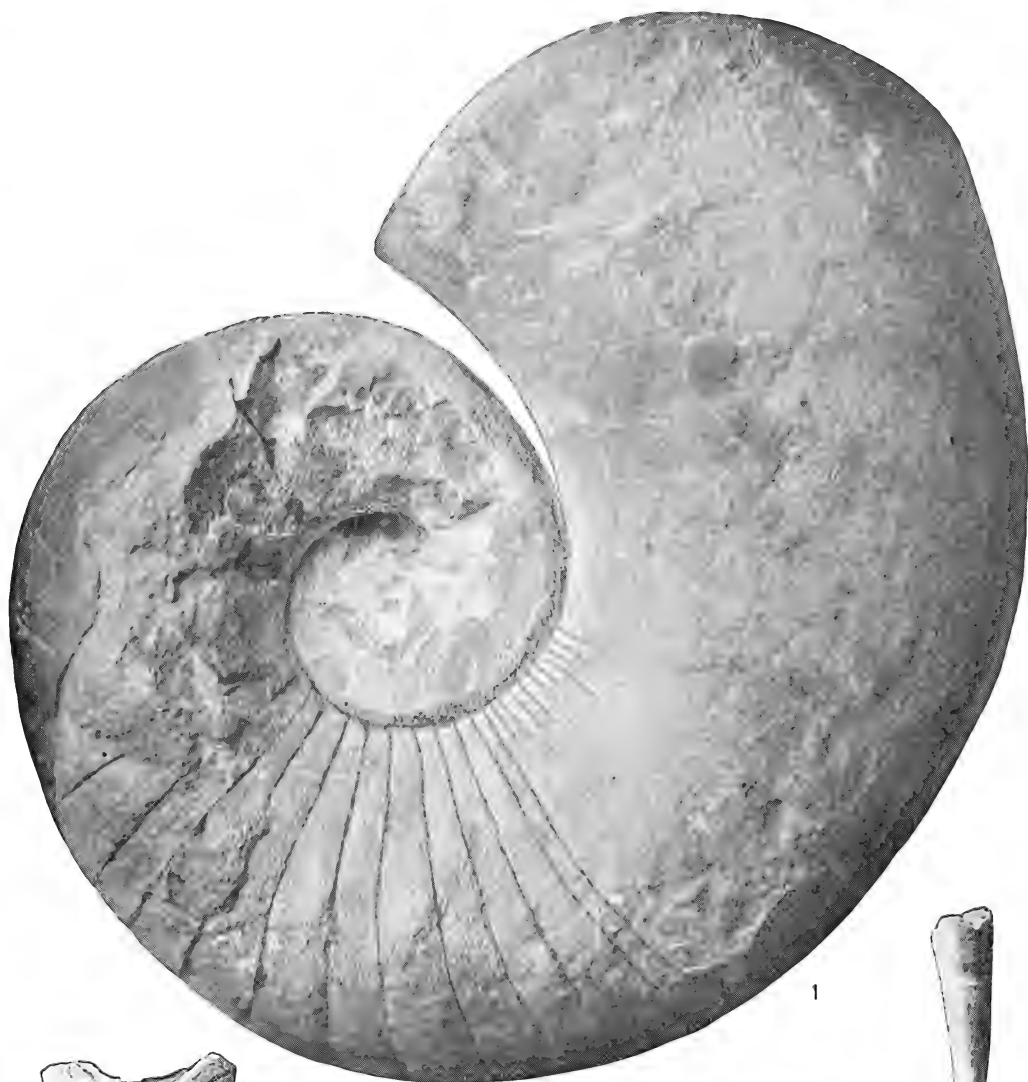


PLATE XXXI

Fig. 1. *Charactoceras baeri* (Meek and Worthen). Lateral view. See also plate XXXII, figs. 1A, B. From vicinity of Oxford, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.

Figs. 2 A, B, C, D. *Tripteroceras hastatum* (Billings). A, ventral side, exposing the siphuncle. B, view of upper end, showing passage of siphuncle through septum. C, diagrammatic lateral view, showing the lateral saddles. D, diagram showing relative depth of dorsal and ventral lobes of the sutures. From Pauquette Rapids, in Ottawa River, Canada, in the Leray member of the Black River. Selected type, numbered 1281, in the Victoria Memorial Museum at Ottawa, Canada.

Figs. 3 A, B, C, D. *Tripteroceras pauquettense* Foerste. A, lateral view. B, ventral view. C, diagram showing relative depth of dorsal and ventral lobes of sutures. D, cross-section at top of specimen, showing passage of siphuncle through septum. Part of the type series of *Tripteroceras hastatum* (Billings), numbered 1281 d, in the Victoria Memorial Museum, at Ottawa, Canada. Selected here as type of new species.

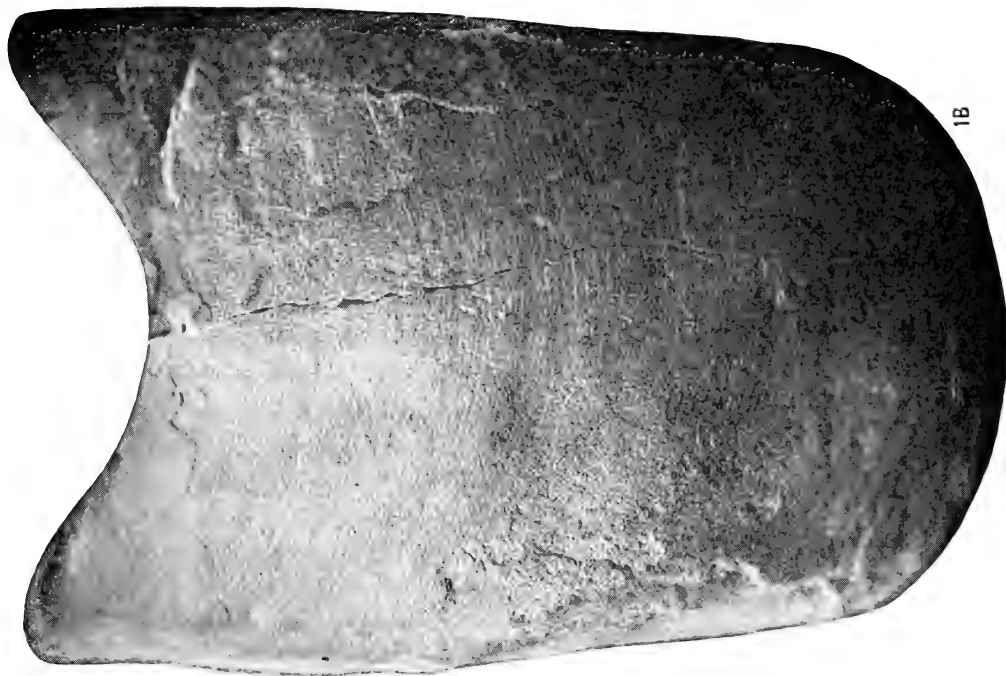


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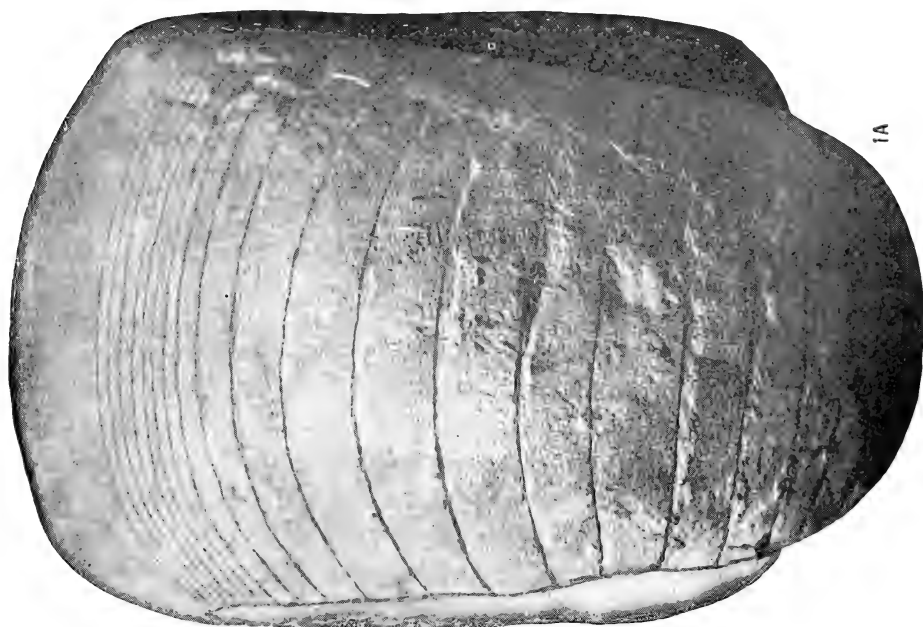
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PLATE XXXII

Figs. 1 A, B. *Characteroceras baeri* (Meek and Worthen). A, ventral view including top of phragmacone and base of living chamber. B, ventral view of living chamber, showing hyponomic sinus. Same specimen as Plate XXXI, Fig. 1.



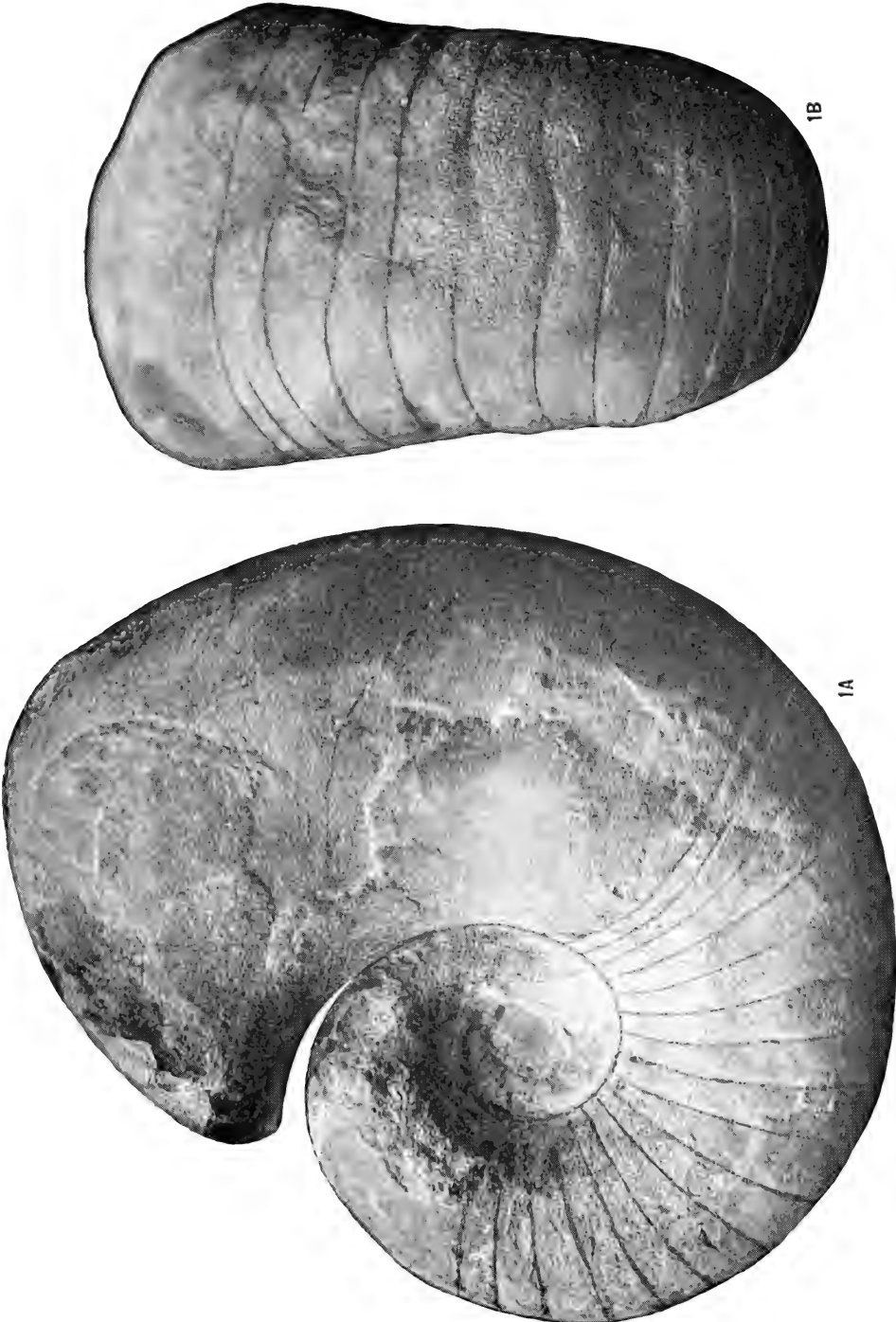
1B



1A

PLATE XXXIII

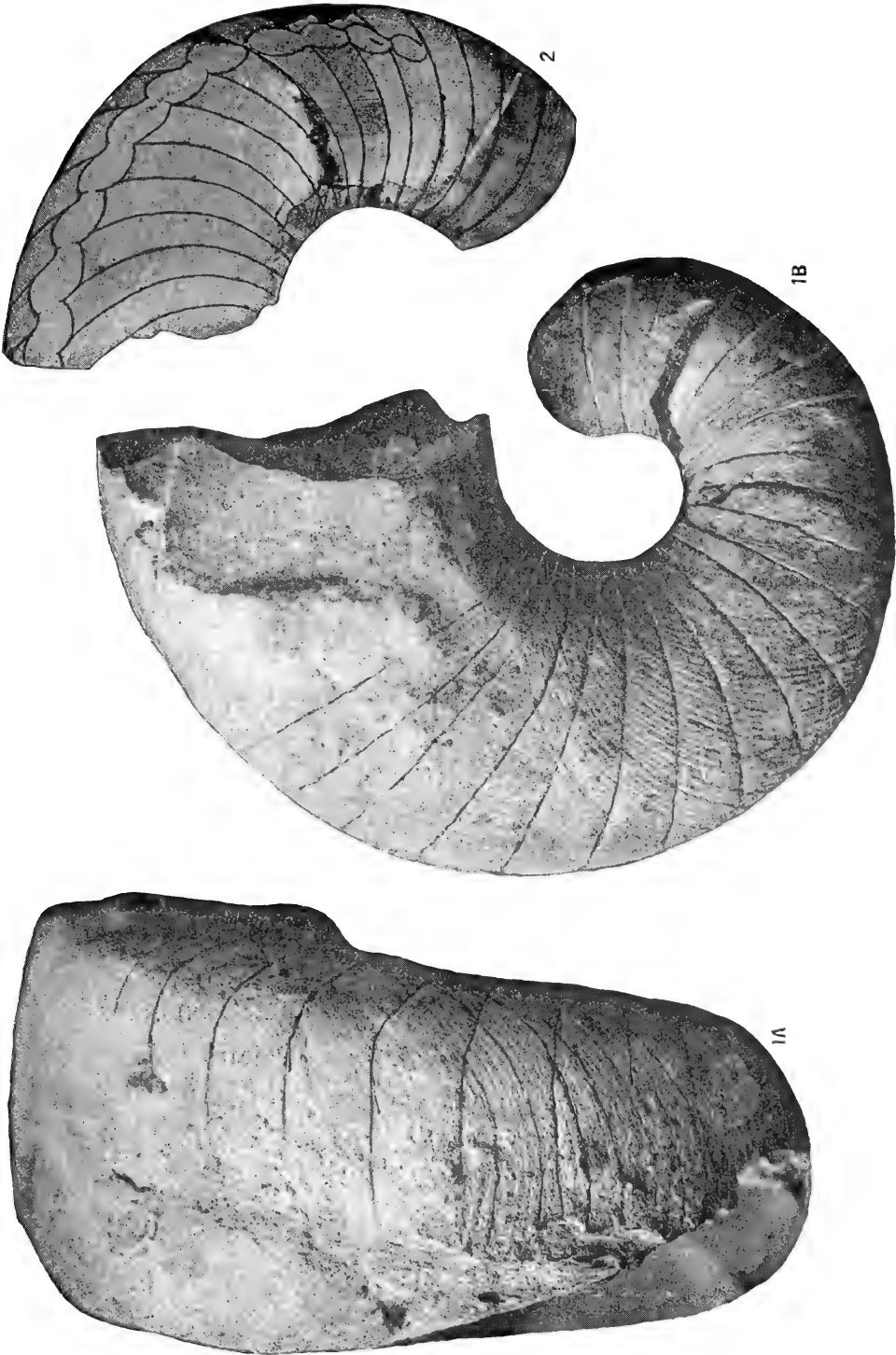
Figs. 1 A, B. *Charactoceras baeri* (Meek and Worthen). A, lateral view. B, ventral view, including upper part of phragmacone and basal part of living chamber. From vicinity of Oxford, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.



#### PLATE XXXIV

Fig. 1 A, B. *Charactoceras baeri* (Meek and Worthen). A, ventral view of an incomplete specimen, showing the surface striae. B, lateral view of the same specimen. From the vicinity of Oxford, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. W. H. Shideler, of Miami University.

Fig. 2. *Charactoceras baeri* (Meek and Worthen). Dorso-ventral section, exposing the siphuncle. From Flat Fork, 4 miles northeast of Oregonia, Ohio, in the basal part of the Whitewater member of the Richmond. Collected by Prof. J. E. Carman, of Ohio State University.



#### PLATE XXXV

Figs. 1 A, B. *Elrodoceras indianense* (Miller). A, B, lateral views of opposite sides of the same specimen, A showing the sutures of the septa, and B showing the surface striae. From some Indiana locality, in the upper part of the Laurel member of the Niagaran. Specimen No. 2133 in the Museum of Comparative Zoology, at Harvard University. Second type of *Rhynchorthoceras dubium* Hyatt. See also Plate XXXVI, Figs. 1A, B.

Figs. 2 A, B, C. *Billingsites* (?) *williamsportense* Foerste. A, lateral view. B, more convex side, assumed to be ventral. C, less convex side, assumed to be dorsal. From Williamsport, Tennessee. Specimen No. 48395, in the U. S. National Museum.



## PLATE XXXVI

Figs. 1 A, B. *Elrodoceras indianense* (Miller). A, ventral view showing the surface striae. B, opposite side of same specimen, showing the camerae, and the top of the siphuncle. From some locality in Indiana, in the upper part of the Laurel member of the Niagaran. Chief type of *Rhynchoroceras dubium* Hyatt, numbered No. 2132, in the Museum of Comparative Zoology, at Harvard University.

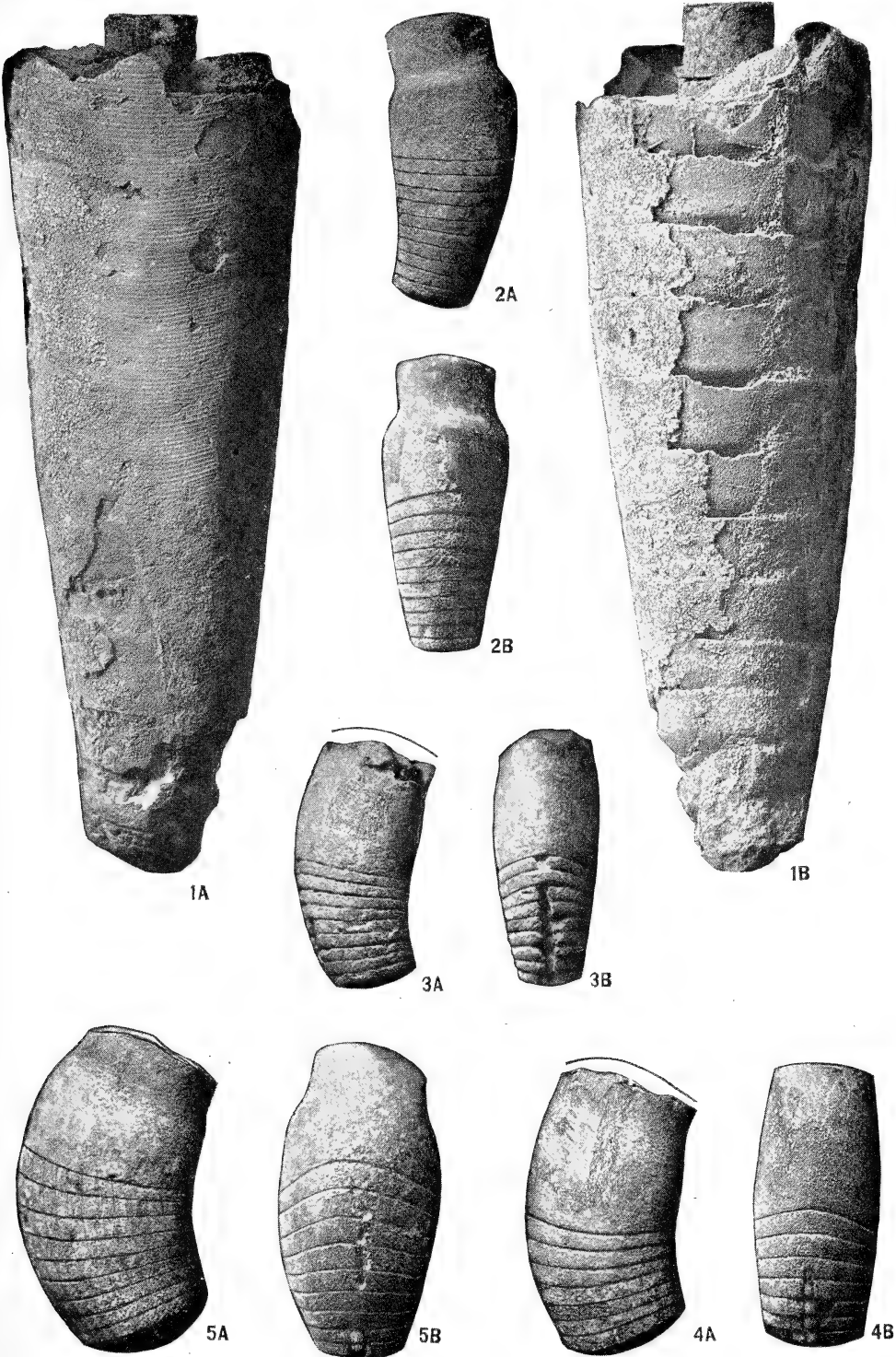
Figs. 2 A, B. *Beloitoceras lycum* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. No. 999, in the American Museum of Natural History. Same specimen as Amer. Mus. Nat. Hist., Bull. 1, pt. 2, 1895, pl. 9, figs. 13, 14. See also Plate XLI, figs. 6 A, B, in this Journal.

Figs. 3 A, B. *Beloitoceras plebeium* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. Specimen numbered 996, in the American Museum of Natural History. Same specimen as that figured by Whitfield, in Bull. Amer. Mus. Nat. Hist., 1, pt. 2, 1895, pl. 9, figs. 18, 19.

Figs. 4 A, B. *Beloitoceras plebeium* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. Specimen numbered 996, in the American Museum of Natural History. Same specimen as that figured by Whitfield, in Bull. Amer. Mus. Nat. Hist., 1, pt. 2, 1895, pl. 9, figs. 15, 16. See also Plate XLI, figs. 5 A, B.

Figs. 5 A, B. *Beloitoceras pandion* (Hall). A, lateral view, cast of interior. B, ventral view. From Beloit, Wisconsin, in the Beloit member of the Black River. Specimen numbered 998, in the American Museum of Natural History. Same specimen as that figured by Whitfield, Bull. Amer. Mus. Nat. Hist., 1, No. 2, pl. 9, figs. 21, 22. See also Plate XLI, figs. 4A, B, C.

The lines over figures 3A and 4A indicate the probable outline of the aperture on lateral view.



## PLATE XXXVII

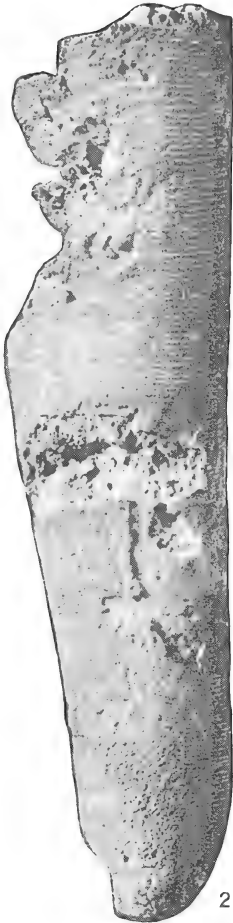
Fig. 1. *Monocyrtoceras lenticulatatum* Foerste. Lateral view, exposing one segment of the siphuncle at the base. See also Plates XXXVIII, fig. 1; XXXIX, fig. 1; XL, figs. 1 A, B; and XLI, figs. 3 A, B. From Greenfield, Wisconsin, in the Racine member of the Niagaran. Specimen No. 2315 in the Museum of Comparative Zoology, at Harvard University.

Fig. 2. *Elrodoceras indianense* (Miller). Ventral side, retaining the transverse surface striae. From Hartsville, Indiana, in the Laurel member of the Niagaran. Same specimen as that figured by Miller, in 17th Ann. Rep. Dep. Geol. Nat. Res. Indiana, 1892, pl. 18, fig. 2.

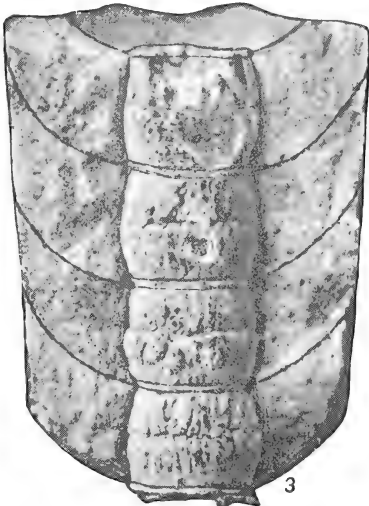
Fig. 3. *Elrodoceras* cf. *indianense* (Miller). Natural section, exposing the siphuncle. From Lemont, Illinois, in the Niagaran. Specimen No. 22917, in the Museum of Comparative Zoology, at Harvard University. See also Plate XXXVIII, fig. 2.



1



2



3

PLATE XXXVIII

Fig. 1. *Monocyrtoceras lentidilatatum* Foerste. Ventral view, exposing one segment of the siphuncle at the base. Same specimen as Plate XXXVII, fig. 1.

Fig. 2. *Elrodoceras indianense* (Miller). Lateral view, with ventral side on right; exposing 4 segments of the siphuncle. Same specimen as Plate XXXVII, fig. 2.

Fig. 3. *Elrodoceras* cf. *indianense* (Miller). Lateral view of part of cast of interior of siphuncle, showing relative size of passage of siphuncle through septum at top of specimen. From Joliet, Illinois, in the Niagaran. No. 22916, in Walker Museum, at University of Chicago.

Fig. 4. *Actinoceras* sp. Lateral view of cast of interior of siphuncle, showing nature of deposits here. From Joliet, Illinois, in the Niagaran. Also numbered 22916, in Walker Museum, but belonging to a different species from the preceding.



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PLATE XXXIX

Fig. 1. *Monocyrtoceras lentidilatatum* Foerste. Dorsal view, inverted in order to illuminate the side best preserved; with one segment of the siphuncle exposed. Same specimen as Plate XXXVII, fig. 1.

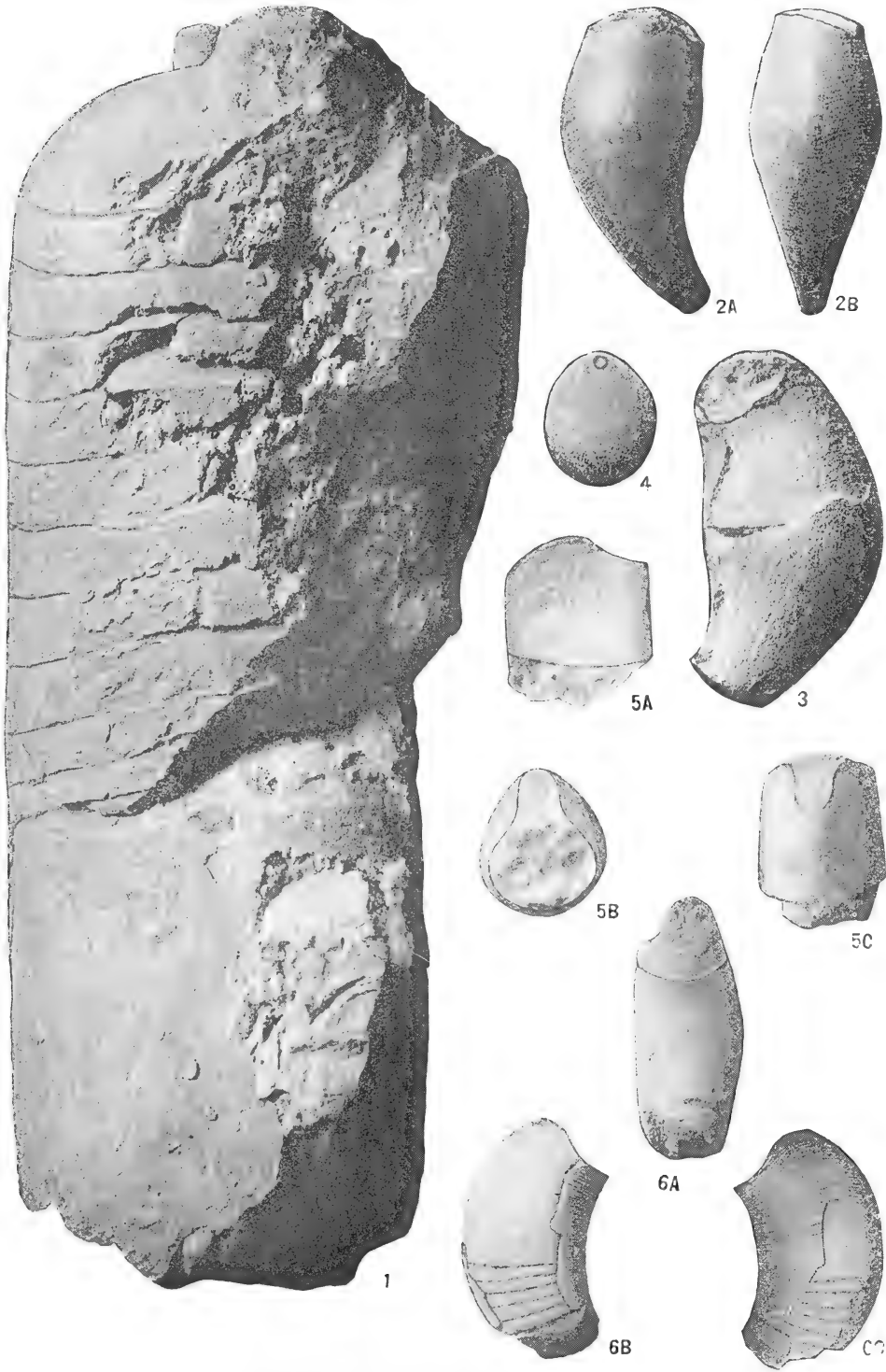
Fig. 2A, B. *Oncoceras constrictum* Hall. A, lateral view; B, ventral view of same specimen, showing surface striae. From Middleville, New York, in the Trenton limestone. Same specimen as 3rd Rep. New York State Museum, 1850, pl. 3, figs. 3 a, b.

Fig. 3. *Oncoceras constrictum* Hall. Lateral view, exposing base of living chamber. From Middleville, New York, in the Trenton limestone. Same specimen as Pal. New York, 1, 1847, pl. 41, figs. 6 a, b, c.

Fig. 4. *Oncoceras constrictum* Hall. View of septum at base of another specimen, showing passage of siphuncle through septum. From Middleville, New York, in Trenton limestone. Same specimen as Pal. New York, 1, 1847, pl. 41, figs. 7 a, b, c.

Figs. 5 A, B, C. *Maelonoceras billingsi* Foerste. A, lateral view, with ventral side on left. B, view of aperture. C, ventral view. From LaCloche Island, in northern Lake Huron, in the Black River. Specimen No. 1294, in Victoria Memorial Museum. One of two specimens described and figured by Billings under *Phragmoceras praematurum*.

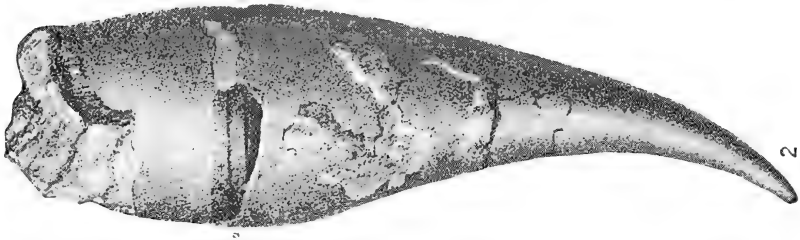
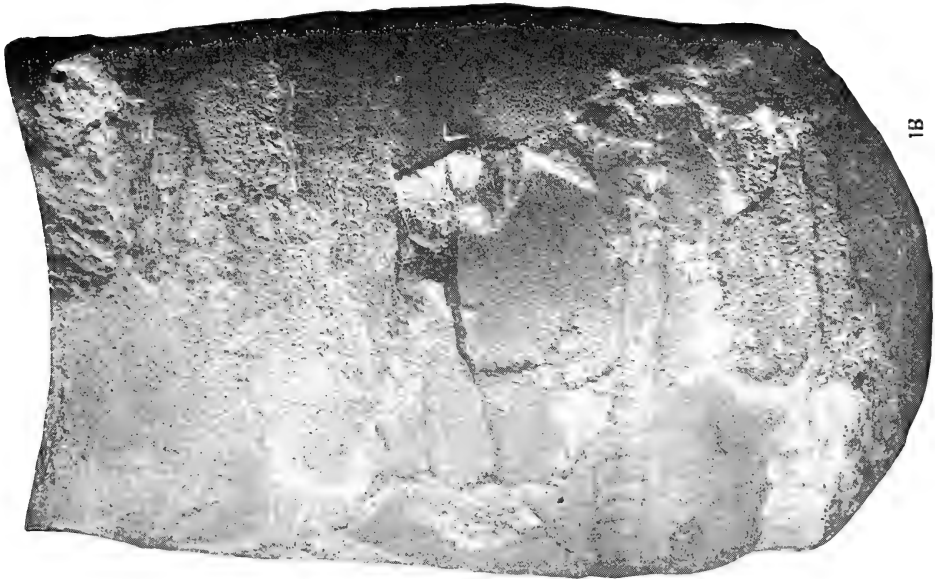
Figs. 6 A, B, C. *Maelonoceras praematurum* (Billings). A, dorsal view. B, lateral view with ventral side on left. C, lateral view with ventral side on right, surface showing transverse striae. From LaCloche Island, in northern Lake Huron. One of two specimens described and figured under *Phragmoceras praematurum*. See also Plate XLI, fig. 7.



#### PLATE XL

Figs. 1A, B. *Monocyrtoceras* cf. *lenticulatum* Foerste. A, lateral view; B, ventral view. Neither presents the outline of the aperture, although the full height of the living chamber appears to be retained by the specimen. From Wauwatosa, Wisconsin, in the Racine member of the Niagaran. Specimen No. 2312, in Museum of Comparative Zoology, at Harvard University.

Fig. 2. *Poterioceras fusiforme* (Sowerby). Lateral view. Copied from Foord, Carb. Ceph. Ireland, 1897, pl. 15, fig. 2b. From the Carboniferous.



## PLATE XLI

Figs. 1 A, B. *Poterioceras fusiforme* (Sowerby). Diagram, showing outline of conch, course of sutures along upper part of phragmacone, and vertical section through lower part of specimen. B, siphuncle of same specimen, enlarged. From Kildare, Ireland, in the Carboniferous. Specimen No. 2177, in the Museum of Comparative Zoology, at Harvard University.

Fig. 2. *Charactoceras baeri* (Meek and Worthen). Cross-section at three points across the same phragmacone, to show the change in form with age. Same specimen as Plate XXXIV, fig. 2.

Fig. 3 A, B. *Monocyrtoceras lentidilatatum* Foerste. A, cross-section showing location of siphuncle. B, dorso-ventral section, showing general outline of siphuncle. Same specimen as Plate XXXVII, fig. 1.

Fig. 4 A, B, C. *Beloitoceras pandion* (Hall). A, outline of aperture. B, cross-section of conch. C, dorso-ventral section through siphuncle, enlarged. Same specimen as Plate XXXVI, figs. 5 A, B, C.

Figs. 5 A, B. *Beloitoceras plebeium* (Hall). A, outline of aperture. B, cross-section of conch, at largest diameter. Same specimen as Plate XXXVI, figs. 4 A, B, C.

Figs. 6 A, B. *Beloitoceras lycum* (Hall). A, cross-section of conch at largest diameter. B, dorso-ventral section through siphuncle. Same specimen as Plate XXXVI, figs. 2 A, B.

Fig. 7. *Maelonoceras praematurum* (Billings). Vertical dorso-ventral section, showing fusiform segments of siphuncle. Same specimen as pl. XXXIX, figs. 6 A, B, C.

Fig. 8. *Clarkoceras mercurius* (Billings). Vertical dorso-ventral section, with siphuncle on left side, showing concave vertical outline of segments of the siphuncle; enlarged. Diagrammatic drawing prepared from the type specimen No. 826, in the Victoria Memorial Museum, at Ottawa, Canada. Originally described under *Cyrtocerina*.

Fig. 9. *Cyrtocerina typica* Billings. Vertical dorso-ventral section, with siphuncle on left side, showing convex vertical outline of segments of the siphuncle; enlarged. Diagrammatic drawing prepared from the type specimen, No. 1301, found at Pauquette Rapids, on Allumette Island, in the Black River formation. In Victoria Memorial Museum, at Ottawa, Canada.

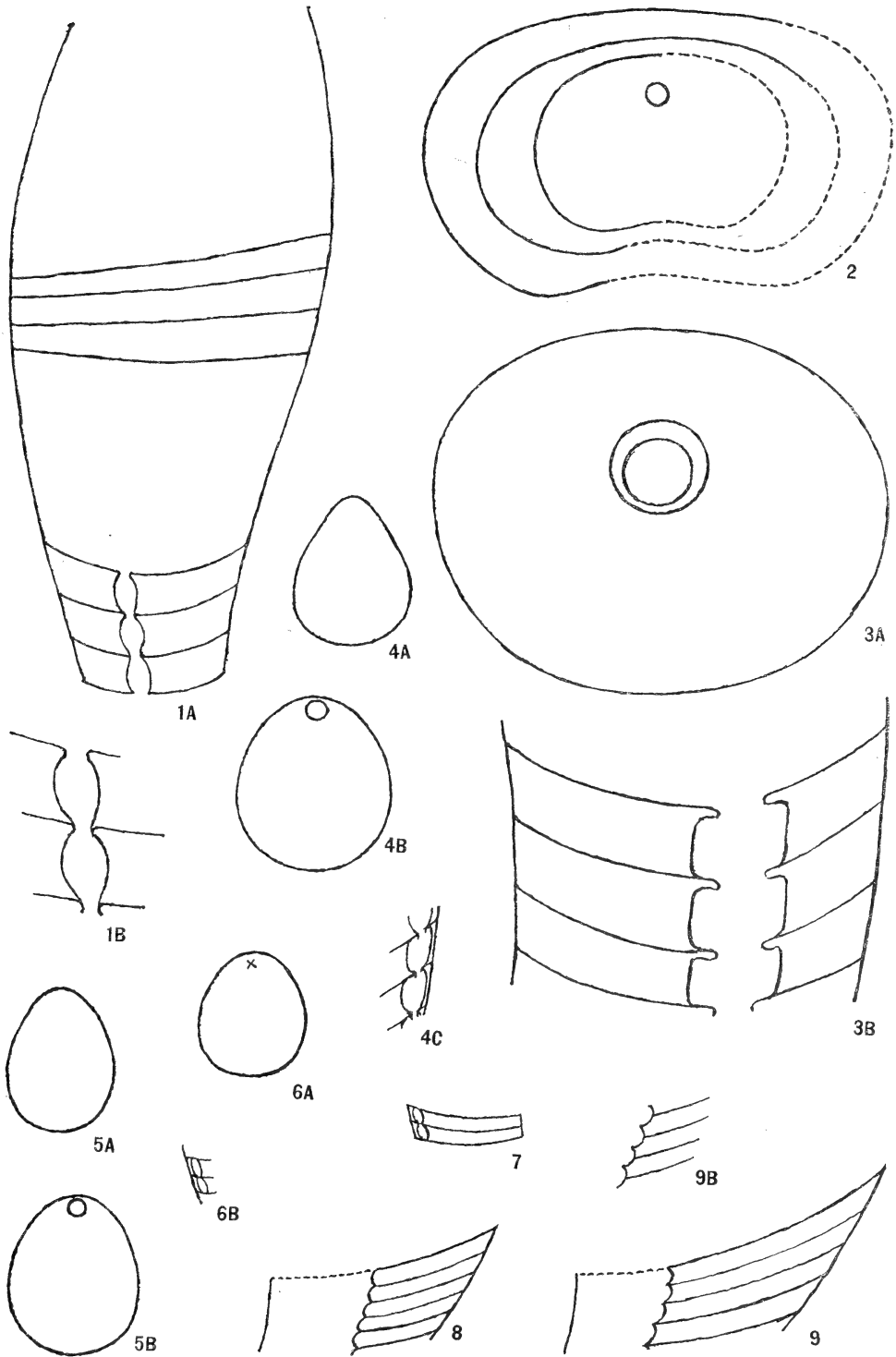
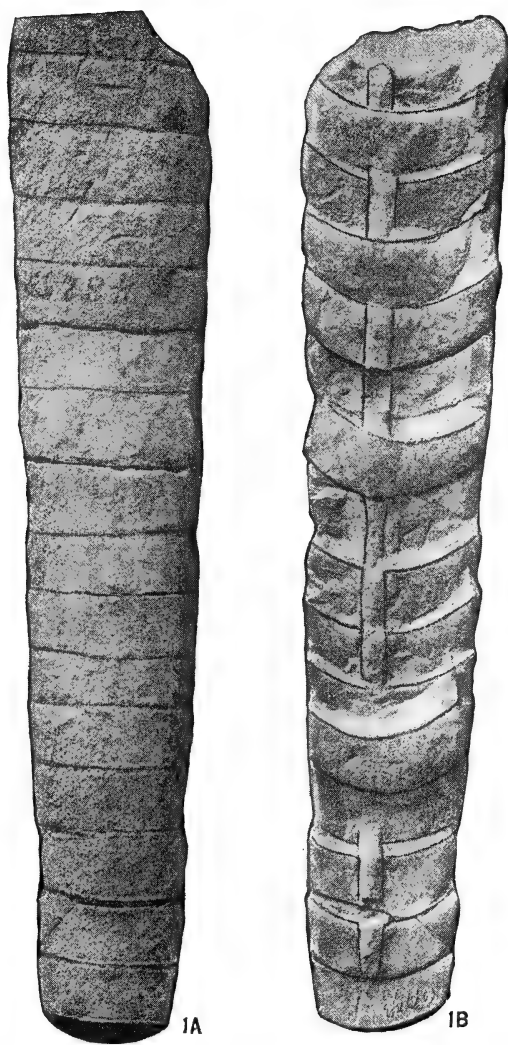


PLATE XLII

Figs. 1 A, B. *Orthoceras clarksvillense* Foerste. A, cast of interior of conch. B, natural vertical section of same specimen, showing the cylindrical segments of the siphuncle. Specimen No. 48255, in the U. S. National Museum. From the Waynesville member of the Richmond formation at Clarksville, Ohio.





## A REPORT ON THE THEORY OF RELATIVITY. (EINSTEIN THEORY)

PAUL BIEFELD

During the past twenty-five to thirty years phenomenal work has been done in the physical sciences. We need only recall X-rays, followed by radioactivity, then electrons and wireless. The experimental work along these lines has, however, also brought into question some of the fundamental principles of the science itself; leading to the abandonment, notably, of the following three: the unchangeableness of the atom, the independence of space and time, and the continuity of dynamical action. The letting go of the first led to the electron theory, of the second to the theory of relativity, and of the third to the quantum theory. The corner stones of the structure have, however, been in no wise affected. The principle of the conservation of energy and that of the conservation of mass, although the latter has been merged into the first by the restricted theory of relativity; the laws of thermodynamics; the principle of least action; all of these have been all the more firmly established. They have stood the fire of searching experiment of modern physics.

### The Restricted Principle of Relativity

It is necessary at the outset to consider the concepts of space and time, in particular the relation of these concepts to experience. In this connection the terms "absolute space" and "absolute time" have no meaning. The physicist thinks of space only in connection with the occurrence of events. In fact it is not even the point in space 'where' something is, nor the instant of time 'when' something happens, but the event itself, that is to him the only physical reality.

We shall consider the distance or space interval between two points referred to a body of reference or frame of reference expressed in Cartesian coordinates. Calling  $x_1, x_2, x_3$  the coordinates, the interval becomes:

$$s^2 = \Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2 \quad (1)$$

in which the  $\Delta x$ 's are the projections of the interval on the axes,

the axes being thought of as rigid rods and the unit length a short rigid bar.

Time is expressed by means of a body, or system, called a clock that counts off events, the intervals between them being considered of equal length.

Time and space as above defined serve only to represent to the physicist the complex of experiences relating to the events observed by him.

To give a physical significance to the concept of time and to establish definite relations between different points in space a physical process of some kind must be used. As the propagation of electromagnetic radiations or light in vacuum is the one that has been most accurately investigated and determined, this is chosen for the purpose; not for the reason, however, as has been brought forward by some of the objectors to the theory, that this particular process is essential to the theory; any other equally well determined process would serve as well.

There are two postulates on which the theory rests: the principle of relativity and the constancy of the velocity of light; stated definitely as follows:

1. The laws according to which the physical conditions of systems change are independent of the fact to which of two frames of reference, having relative uniform rectilinear motions, these changes of conditions are referred. (Relativity of uniform motions.)

2. Light has a definite and constant velocity "c" in a frame of reference at rest, independent of the fact whether the source of light is in motion or at rest.

Let a clock be placed at a point A where an observer may "time" an event in its immediate vicinity and a second similar clock placed at a point B where a second observer may "time" an event in a similar manner; this does not lead, however, without further consideration to the fact that the times of the events at A and B may be directly compared. For we have up to this time only defined a 'time at A' and a 'time at B' but not a 'common time.' This common time will now be defined by means of the second postulate; stating, that it takes the same time for light to travel from A to B, as it does to go from B to A.

We therefore send a light signal from A to B where it is reflected to A. Let  $t_A$  be the time at A or the 'A-time' and  $t_B$  be the

time at B or 'B-time' and  $t'_A$  the time of arrival of the reflected ray at A. The clocks then run synchronously if  $t_B - t_A = t'_A - t_B$ . This equation defines 'time' and 'simultaneity of time'. The velocity of light is then also defined by:

$$c = \frac{2AB}{t'_A - t_A} \quad (2)$$

We may now assume the uniform velocity of light in all directions, there being no reason for assuming the direction A-B as unique.

Assuming now A as the source of light and at the same time the origin of a frame of reference K at rest. If  $r$  is the distance of the point B from A; after the time  $\Delta t$  the wave front will be the surface of sphere passing through B, for according to the second postulate the equation holds:

$$r = c \cdot \Delta t$$

If we express the difference of coordinates by  $\Delta x_v$ ,  $v$  from 1 to 3, and squaring we get

$$\sum (\Delta x_v)^2 - c^2 \Delta t^2 = 0 \quad (3)$$

This equation evidently formulates the principle of the velocity of light relative to K which must be independent of the motion of the source A.

We now take another frame of reference K' in uniform rectilinear motion relative to K. K and K' are then inertial systems.

With respect to K' we have the equation:

$$\sum (\Delta x'_v)^2 - c^2 \Delta t'^2 = 0 \quad (3a)$$

Equations (3) and (3a) must be mutually consistent with each other with respect to a definite transformation, transforming K' into K. Again an interval has a physical meaning only if it is independent of the choice of coordinates which is true evidently also of the spherical surfaces represented by (3) and (3a).

We will now develop the Lorentz transformation in an elementary way.

Let the  $x_1$  coordinate axis be parallel to the  $x'_1$  axis and  $x_2 = x'_2$  also  $x_3 = x'_3$  of K and K' respectively. Furthermore we must have:

$$x_1^2 - c^2 t^2 = x_1'^2 - c^2 t'^2 \quad (4)$$

and

$$x'_1 = k(x_1 - vt); \quad x_1 = k'(x'_1 + vt') \quad (5)$$

in which  $k$  and  $k'$  are constants depending only on  $c$ , the velocity of light; and  $v$ , the relative velocity of  $K'$  with respect to  $K$ . We calculate now from the second equation of (5) with the aid of the first of (5):

$$t' = k \left[ t - \frac{x_1}{v} \left( 1 - \frac{1}{kk'} \right) \right] \quad (6)$$

and put the value of  $x'_1$  and  $t'$  from (5) and (6) into equation (4). A comparison of the coefficients of  $x'_1$ ,  $t^2$  and  $x_1 t$  leads to:

$$k = k' = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

Substituting  $k$  and  $k'$  in (5) and (6) we get:

$$x'_1 = \frac{x_1 - vt}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad t' = \frac{t - \frac{v}{c^2} x_1}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad \text{and } x'_2 = x_2, \quad x'_3 = x_3 \quad (7)$$

Solving for  $x_1$ ,  $t$ ,  $x_2$  and  $x_3$  we get:

$$x_1 = \frac{x'_1 + vt'}{\sqrt{1 - \frac{v^2}{c^2}}}, \quad t = \frac{t' + \frac{v}{c^2} x'_1}{\sqrt{1 - \frac{v^2}{c^2}}} \quad \text{and} \quad x_2 = x'_2, \quad x_3 = x'_3 \quad (8)$$

These equations were for the first time developed by H. A. Lorentz hence the name "Lorentz transformation."

Let us place a number of synchronous clocks in the system  $K$ . If their rates are zero they will remain synchronous. Some of these clocks are now transferred to the system  $K'$  having its axes parallel to those of  $K$  and moving relative to  $K$  with a uniform rate parallel to the  $X_1$  axis. The clocks in  $K'$  as seen by an observer at rest in  $K$ , will depart from synchronism relative to the clocks in  $K$ , losing time or going slower. Rods of definite length as measured in  $K$  if placed in  $K'$  after they have been given the same motion as the system  $K'$ , and placed in the  $X'_1$  axis will seem contracted as viewed by the same observer at rest in  $K$ . If the velocity of  $K'$  with reference to  $K$  is known, both the change of rate of the clocks and the contraction of the rods may be numerically accounted for by means of the Lorentz transformation given above. It is of course evident that these changes will be extremely small on account of the second order effect:  $\sqrt{\frac{v^2}{c^2}}$  occurring in the equation. If for instance  $v$  were as large as the orbital velocity of the earth, 18.5 miles per second, the value of the expression just given would be of the order  $10^{-8}$ .

It was also H. A. Lorentz who adopted the so-called contraction theory, first suggested by Fitzgerald, to satisfy his equations in connection with electron motion; assuming the contraction to be real the electrons taking on ellipsoidal form with their shorter axes in the direction of motion; hence the term "Lorentz contraction." In this theory there would, however, be involved some relation of this contraction to a corresponding physical change within the electron varying with the speed of the electron of which there is no trace. Einstein solved the enigma with one stroke by establishing the relativity of time and space leading to the same Lorentz equations but on a more rational basis.

Prof. Lorentz has the following to say in his Columbia lectures already referred to: "... he (Einstein) may certainly take credit for making us see in the negative result of experiments like those of Michelson, Rayleigh and Brace, not a fortuitous compensation of opposite effects, but the manifestation of a general and fundamental principle." And again: "It would be unjust to add that, besides the fascinating boldness of his starting point, Einstein's theory has another marked advantage over mine, whereas I have not been able to obtain for the equations referred to moving axes 'exactly' the same form as for those which apply to a stationary system, 'Einstein' has accomplished this by means of a system of new variables slightly different from those which I have introduced."

This was written in 1909 four years after the publication of Einstein's work on the Restricted theory, after the theory had been tested by Kaufman and Bucherer in connection with the extremely rapid moving  $\beta$ -rays establishing the forms for the longitudinal and transverse mass of the electron as:

$$m_l = \frac{m_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)^3}} \quad . \quad m_t = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

distinguishing between the instantaneous motion in the x-direction as transverse, attaching these terms to the respective masses. At the present time the form has been simplified agreeing with that given by Lorentz in 1904, namely:

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

where  $m$  is the mass in motion,  $m_0$  the mass at rest of the electron.

The principle is, however, not only true in connection with masses of electrons but also with respect to every ponderable mass as will be shown later.

Returning now to equations (3) and (3a) we will introduce the so-called 'light time,'  $l=ct$ ; using this, these equations become:

$$\Sigma (\Delta x_\nu^2 - \Delta l^2) = 0 \quad (9)$$

$$\Sigma (\Delta x_\nu'^2 - \Delta l'^2) = 0 \quad (9a)$$

and the Lorentz transformation makes (9) a covariant equation which is satisfied with reference to every inertial system  $K'$ , having a uniform rectilinear motion relative to  $K$ , if it is satisfied in the system  $K$  to which we have referred the two events: emission and reception of electromagnetic radiations or light.

At this point the genius of Mincowski steps in, introducing the time coordinate:  $x_4 = il$  ( $i = \sqrt{-1}$ )

and equation (9) becomes:

$$\Sigma x_\nu^2 = 0 \quad \nu \text{ from 1 to 4} \quad (10)$$

and (9a)

$$\Sigma x_\nu'^2 = 0 \quad \nu \text{ from 1 to 4} \quad (10a)$$

Thus putting at once the time coordinate  $x_4$  formally on the same footing as the space coordinates  $x_1, x_2, x_3$ . We say formally only because the relation of rationality must be considered. The space-time frame of reference of (10) and (10a) is Euclidean with one imaginary coordinate.

A point  $x_1, x_2, x_3, x_4$  is called a 'world-point' and the line generated by the same a 'world-line,' and the continuum the 'world.' All events present themselves to the observer as intersections of world lines. Thus the event "twelve o'clock" as observed on a watch comes to us as the intersection of a world line through a point on the dial with a world line through a coincident point on the hands of the watch.

We shall now give another interesting consequence of the restricted theory.

According to this theory the conservation of mass, or more

strictly speaking of 'inertia mass,' has lost its meaning and is merged, as was indicated in the introduction, with the principle of the conservation of energy.

We have already treated of the change of mass of electrons by virtue of their motion and indicated there that the same was true of any mass. This comes about in the following way. The inertia mass changes if it takes up energy of radiation from without. The kinetic energy of a point mass in the pre-relativity mechanics is expressed by:

$$\frac{mv^2}{2}$$

according to relativity by:

$$\frac{mc^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

This expression becomes infinite as  $v$  approaches  $c$ , showing in the first place that it can not become equal to  $c$ , involving as this would an infinite amount of kinetic energy possessed by a point mass.

If the expression above is expanded in series we have:

$$mc^2 + m \frac{v^2}{2} + \frac{3}{8} m \frac{v^4}{c^2} + \dots$$

The second term is the one standing for the kinetic energy in the old mechanics, the third term is very small if  $\frac{v^2}{c^2}$  is small in comparison with unity, and the first term does not contain  $v$ ; its meaning will come out in the subsequent discussion. If a moving body according to electrodynamics takes up the energy  $E$  in form of radiation, the increase of energy becomes:

$$\frac{E_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

and the energy of the body becomes:

$$\frac{(m + \frac{E_0}{c^2})c^2}{\sqrt{1-\frac{v^2}{c^2}}}$$

This body has therefor the same energy as a body of mass:

$$m + \frac{E_0}{c^2}$$

If we write the expression in the form:

$$\frac{mc^2 + E_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

we see that the expression  $mc^2$  in the expansion is the energy which the point mass possessed before the body took up the energy  $E$ .

### The General Theory of Relativity. (Theory of Gravitation).

The restricted theory is valid only in connection with bodies or frames of reference in uniform rectilinear motion relative to each other. There is no reason thinkable, however, why such systems should be preferred for other systems having any kind of motion; for we find nowhere in nature any such distinction indicated either in bodies or in the concept of motion. We are compelled then to look for the distinction as resting in the objective properties of the space-time continuum. We must attribute to this continuum a "field property" as we do in case of the electromagnetic field; and then find a way to extend the principle of relativity to frames of reference in non-uniform motion relative to each other.

We find a way of attack by the following consideration. In physics the ratio of the masses of two bodies is defined in two ways: first, as the inverse ratio of the accelerations imparted to them by the same force producing the motion; second as the direct ratio of the forces acting in the same gravitational field. In the first relation we call the mass "inertia mass" in the second "gravity or weight-mass." The ratio of these two masses have been found by Oetvoes so nearly equal to unity that the deviation is of the order of less than  $5 \times 10^{-8}$ . The examination included substances of crystalline structure and of radioactive nature. Inertia and gravity mass are then not only proportional but strictly equal. We have, however, no right in face of these results to maintain such an equality in thought unless it is reduced to an equality of nature of the two concepts. The statement of the equality of inertia-mass and gravity-mass is equivalent to the statement that the acceleration imparted to a body in a gravitational field is independent of the nature of the body; and it is the

extension of the principle of relativity that will establish the equality of the real nature of the two concepts.

A simple hypothetical experiment pointing to this extension will make the point made in the last paragraph clear. Let us consider a cubical box of sufficient size so that an observer provided with appliances for experiment finds room in the same. We further conceive of this box so far away from all bodies or masses so that it is not influenced by them in a gravitational way. The observer will experience great difficulty to stand upright. When lying on the floor the least impulse will send him to the ceiling. When he lets go of an object in his hand it will not fall to the floor. A body attached to a string fastened to the ceiling will not stretch the string unless pulled down by the observer which he would find hard to do on account of the instability of the bodies involved.

Let us now imagine a rope attached to the outside of the box and some being begin to pull at the same upward with a constant force, giving the box a uniform acceleration. The man inside the box will at once be able to stand upright in the box. Letting go of an object it will fall to the floor; looking at the body on the string he will see it hanging vertical with the string taut. In view of the observed facts the man has every reason to believe that he is in a "gravitational field."

Now let us further imagine an observer located at rest in space some distance to one side of the box. This observer would be of different opinion from the one in the box; he would say, the reason the string hangs taut and hangs in a vertical direction is due to the "inertia" of the upward accelerated box; and give a similar explanation with regard to the other phenomena occurring there.

The observer in the box then attributes to the body on the string "gravity mass"; the observer outside the box, "inertia mass." The two concepts are identical and, moreover, independent of the nature of the body.

Within the box the actual acceleration of bodies is strictly "equivalent" to a gravitational field.

We may now substitute for the box a frame of reference  $K'$  limited, however, to the confines of the box; and for the region outside, where the second observer is located, a frame of reference  $K$ .  $K'$  is uniformly accelerated with respect to  $K$ . Relative to  $K'$  or as seen from  $K'$ ,  $K$  is uniformly accelerated.  $K'$ , as seen

by the observer within, is at rest and a gravitational field present. This gravitational field may then be legitimately replaced, within the limits of the box, by the accelerated coordinate system  $K'$ . This principle of equivalence is evidently intimately related to the equality between the inertia-mass and gravitational-mass, and leads thus to the extension of the principle of relativity to frames of reference that are in non-uniform motion with reference to each other. Again this conception leads to the unity of the nature of inertia and gravitation.

It is to be noted, however, that a gravitational field can be replaced by a frame of reference having a uniform acceleration only within a very limited portion of space; about in the same way as we can think of a plane sheet of paper being in contact with a curved surface over only a very limited part of the surface. Nevertheless the principle of equivalence gives us the correct mode of attack to conquer the difficulties of the general theory of relativity. For as Einstein says in his Princeton lectures of 1921: "The possibility of explaining the numerical equality of inertia and gravitation gives to the general theory of gravitation, according to my conviction such a superiority over the conception of the classical mechanics, that all the difficulties encountered in the development must be considered as small in comparison."

In the general theory then we must do away with preferred systems of reference of any kind, the term 'gravitational field' involving all arbitrarily moving frames of reference of any kind.

Let us now consider one of the simplest of such fields present in case of a rotating system. Let  $K'$  be a frame of reference whose  $x'_3$ -axis coincides with the  $x_3$ -axis of the system  $K$  at rest.

We put the question: Are the configurations of rigid bodies at rest relative to  $K'$  (that is, moving with  $K'$ ) in accord with Euclidean geometry?

As  $K'$  is not an inertial system we do not know directly the configurations of rigid bodies with reference to  $K'$ .

Let us take a circle in the  $x'_1$ — $x'_2$  plane and a diameter of this circle. Further let us place a sufficient number of very small rigid rods of the same length along the circle and the diameter; then the ratio of the number in the circle to the number in the diameter come out equal to  $\pi$ . Let now the system  $K'$  be rotated with uniform angular velocity about  $x'_3$ -axis. We will now find that more rods will have to be placed along the circle while none need be added to the diameter. This is easily explained; for the

rods along the circumference suffer a Lorentz contraction while those along the diameter do not. The ratio of circumference to diameter now comes out greater than  $\pi$ . From this follows that the laws of configuration of rigid bodies does no longer conform to Euclidean geometry. Again if we place two synchronous clocks, one in the center and one in the circumference of the system  $K'$  in uniform rotation, the latter will go slower if observed by someone at the center. From this follows that space and time can not be defined with respect to  $K'$  as they were in the restricted theory.

According to the principle of equivalence  $K'$  is here also to be considered as a frame of reference at rest with respect to which a gravitational field is present. (Field of centrifugal force). We must then come to the conclusion that a gravitational field influences and in fact determines the metrical properties or the 'metrics' of the time-space continuum. If then the laws of configuration of rigid bodies are to be expressed geometrically, the geometry is non-Euclidean.

A similar situation presents itself in the consideration of general two-dimensional surfaces as intimated above. On the plane, Cartesian coordinates  $x_1, x_2$  will suffice to measure any portion of the same by means of rigid measuring rods; not so on the surface of an ellipsoid for instance. Gauss introduced curvilinear coordinates to overcome the difficulty, which satisfying the condition of continuity are wholly arbitrary otherwise. (flexible threads take the place of shord rigid rods). Later these coordinates were related to the metrical properties of the surface. Then Rieman extended the dimensions to any number, establishing infinitesimal geometry to  $n$  dimensions in which the generalized Pythagorean theorem holds. Applying this to our space-time frame of reference of the general principle of relativity we have the arbitrary coordinates  $x_1, x_2, x_3, x_4$  numbering uniquely 'world points' and the invariant interval between two such points.

$$ds^2 = g_{\mu\nu} dx_\mu dx_\nu \quad \text{G from 1—4} \quad g_{\mu\nu} = g_{\nu\mu}$$

in which the  $g_{\mu\nu}$  describe with respect to the coordinates the metrical relations of the continuum and at the same time the gravitational field.

The above expression expanded would become:

$$ds^2 = g_{11} dx_1^2 + g_{22} dx_2^2 + g_{33} dx_3^2 + g_{44} dx_4^2 + 2g_{12} dx_1 dx_2 + 2g_{13} dx_1 dx_3 + 2g_{14} dx_1 dx_4 + 2g_{23} dx_2 dx_3 + 2g_{24} dx_2 dx_4 + 2g_{34} dx_3 dx_4$$

The  $g$ 's are functions of the infinitesimal coordinates; mathematically they are quadratic functions of the infinitesimals.

The  $\mu\nu$ 's may be represented by the symmetrical array:

$$\begin{array}{cccc} 11 & 12 & 13 & 14 \\ 21 & 22 & 23 & 24 \\ 31 & 32 & 33 & 34 \\ 41 & 42 & 43 & 44 \end{array}; \text{ but as the } \mu\nu' s = \nu\mu' s$$

we need only:  $\begin{array}{cccc} 11 & 12 & 13 & 14 \\ & 22 & 23 & 24 \\ & & 33 & 34 \\ & & & 44 \end{array}$

which are the double subscripts

occurring in the above expansion.

In case of the absence of a field of force, the equation becomes that of the restricted theory:

$$ds^2 = -dx_1^2 - dx_2^2 - dx_3^2 + dx_4^2$$

in which  $x_1, x_2, x_3$  are imaginary space coordinates and  $dx_4$  the real time coordinate that can be measured directly by means of a clock. The  $g$ 's in this case are represented then by the following array:

$$\begin{array}{cccc} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & +1 \end{array}$$

As a concrete example we will consider the transformation to rotating axes, the rotating system mentioned on page 278.

The infinitesimal space-time interval of the frame of reference is represented by:

$$ds^2 = -dx^2 - dy^2 - dz^2 + dt^2$$

let  $x_1, x_2, x_3, x_4$  be any functions of  $x, y, z$  and  $t$  then:

$$dx = \frac{\partial f_1}{\partial x_1} dx_1 + \frac{\partial f_1}{\partial x_2} dx_2 + \frac{\partial f_1}{\partial x_3} dx_3 + \frac{\partial f_1}{\partial x_4} dx_4 \dots$$

and this will lead us to the expressions holding in the general theory namely:

$$ds^2 = g_{\mu\nu} \quad \text{as given above.}$$

The relations for transforming to rotating axes are:

$$\begin{aligned} x &= x_1 \cos \omega x_4 - x_2 \sin \omega x_4 \\ y &= x_1 \sin \omega x_4 + x_2 \cos \omega x_4 \\ z &= x_3 \\ t &= x_4; \end{aligned}$$

and we have:

$$\begin{aligned}dx &= \cos \omega x_4 dx_1 - \sin \omega x_4 dx_2 - \omega (x_1 \sin \omega x_4 + x_2 \cos \omega x_4) dx_4 \\dy &= \sin \omega x_4 dx_1 + \cos \omega x_4 dx_2 + \omega (x_1 \cos \omega x_4 - x_2 \sin \omega x_4) dx_4 \\dz &= dx_3 \\dt &= dx_4\end{aligned}$$

Substituting in the equation for  $ds^2$  we have:

$$ds^2 = -dx_1^2 - dx_2^2 - dx_3^2 + [(1-\omega^2)(x_1^2 + x_2^2)]dx_4^2 + 2\omega x_2 dx_1 dx_4 - 2\omega x_1 dx_2 dx_4$$

Comparing this with the expression for

$$ds^2 = g_{11} dx_1^2 + g_{22} dx_2^2 + \dots$$

we get the values of the  $g$ 's:

$$\begin{aligned}g_{11} &= -1 \\g_{22} &= -1 \\g_{33} &= -1 \\g_{44} &= [(1-\omega^2)(x_1^2 + x_2^2)] \\2g_{14} &= 2\omega x_2 \\2g_{24} &= -2\omega x_1\end{aligned}$$

or the array is:

$$\begin{array}{cccc} -1 & 0 & 0 & \omega x_2 \\ 0 & -1 & 0 & -\omega x_1 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & [(1-\omega^2)(x_1^2 + x_2^2)] \end{array}$$

If we put:  $\frac{1}{2}\omega^2(x_1^2 + x_2^2) = \Omega$  then  $g_{44} = 1 - 2\Omega$ , repre-

sents the potential of centrifugal force, or a special type of gravity-potential.

Although the  $g$ 's represent the metrical properties of the space-time continuum, we do not ordinarily look upon them as the field produced by rotating axes. We have other means like the gyro-compass or Foucault's pendulum to present such a field to our minds, yet the field is nevertheless defined by the  $g$ 's and as seen especially in this case, by the  $g_{44}$ .

It must therefor be possible to represent the gravitational field in the specific sense by the  $g$ 's, and Einstein has accomplished this by finding the differential equations satisfied by the  $g$ 's representing this field. These differential equations for the generalized potential express the law of gravitation of Einstein just as the Newtonian law of gravitation is represented by:

$$\Delta^2 \varphi = 0$$

It is important that the two-fold meaning of the  $g$ 's be fixed in mind, namely, that they on the one hand express the metrical properties of space and on the other the potential of a field of force. In the absence of such a field of force the field is called Galilean—in which the law of inertia holds and the  $g$ 's are represented by the array:

$$\begin{array}{cccc} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & +1 \end{array}$$

It is hardly to be attempted here to go into details in deriving Einstein's law of gravitation, as that would involve the development of tensor analysis; but a few interesting facts in connection with the same should be mentioned here.

The complete mathematical analysis had been developed before Einstein attacked the problem. The theory of tensors by Riemann and Christoffel in 1867 and 1896 respectively and by Ricci and Levi Civita in 1901 in connection with the theory of surfaces, non-Euclidean geometry and absolute differential calculus including tensor analysis lay ready at hand.

As an example of tensors may be mentioned the fundamental covariant tensor  $g_{\mu\nu}$  of the second order, used in connection with the transformation to rotating axes above. A tensor of the first order is identical with a vector of common vector analysis, and a tensor of zero order is identical with a scalar. Like vectors, tensors are represented by their components. Tensor analysis represents a very powerful tool for the development of the general theory of relativity, symbolizing the laws of nature in connection with a space-time frame of reference that are consistent with the laws of relativity.

### Mathematical and Experimental Tests of the General Theory of Relativity

Before going into this matter it is well to keep in mind that we are not concerned with the 'proof' of the theory. Einstein himself has said, that no amount of experimental demonstration could prove him correct; and that a single experiment could at any time prove him incorrect.

We are concerned only with a theoretical, experimental or observational test of phenomena predicted on the basis of the

theory. Only three of these tests have so far been suggested by Einstein as possible; the fact being that Newton's law is a very close approximation to Einstein's law, the latter being capable of degeneration into the former.

*Tests.*

First: To account for the inconsistency of the observed advance of the perihelion of Mercury with the theoretical value based on Newton's law of gravitation.

That theoretical astronomers did not know what to do next concerning the discrepancy after trying various schemes follows from the words of Simon Newcomb in his 'Astronomical Constants': "In case where our ignorance is complete all hypotheses which do not violate known facts are admissible." But there was no hypothesis that could make good.

According to observation the line of apsides of the orbit of Mercury revolves in the direction of motion of the planet about the Sun through an angle of 574 seconds of arc in a century. The angle calculated from the perturbations of the planets accounted only for about 531" leaving a remainder of 43" that could not be accounted for.

Einstein's calculations based on his theory of gravitation showed that the Sun's gravitational field at Mercury produced the additional 43" per century required. The effect of the Sun's field on the other planets according to the same law is quite small, on account of their distance from the Sun, amounting to about 8" in the case of Venus, about 4" in the case of the Earth and still smaller amounts in case of the remaining planets. The striking feature of the calculation is the absence of any adjustable constants in the formula used. The only constants appearing are the period of the planet,  $T$ , the semi-major axis of the orbit,  $a$ , and the eccentricity,  $e$ .

Second: The curvature of rays of light coming from fixed stars and passing near the Sun, due to the gravitational field of the latter.

In the first place it follows from the general theory that light travels slower in a gravitational field than in a region devoid of such a field, moreover its path is not a straight line the equation of the geodesic being:

$$\delta \int ds \neq 0$$

or the geodesic in a field of force is curved; the amount of curva-

ture depending on the field strength in the region of the path.

Again a ray of light or electromagnetic radiation possesses energy and hence the equivalent of 'mass,' consequently it is acted upon by a gravitational field, the amount of bending depending on the strength of the field from point to point of the path, and varying besides inversely with the distance from the centre of the Sun. At the surface of the Sun the deflection is predicted to be  $1''.75$

Why there should be a deflection due to the gravitational field of the Sun may be seen by referring back to the principle of equivalence in connection with the hypothetical box-experiment.

Let us imagine the man to one side of the box firing a bullet perpendicualar to the vertical wall of the box. The bullet will pass through the box and out on the other side. In the space out side it will fly in a straight line being in a field free of force; inside the box, however, it will be deflected downward. Interpreted by the man in the box as due to a gravitational field and by the man outside due to the upward acceleration of the box. In the case of a ray coming from a star the ray takes the place of the mass of the flying bullet, by virtue of energy of radiation having the equivalent of mass; and the accelerated box being equivalent to a gravitational field, taking the place of the Sun's gravitational field. The analogy is of course only approximate, the 'equivalence' holding only within the confines of the box.

We will now give the results of the observational test of the

### Light Deflections Observed at the 1919 and 1922 Eclipses

Eclipse	Expedition	Telesc.	No. of plates	No. of stars	Ang. dist. fr. Sun	Range of deflect	Res.	P. E.	Observers
1919	Sobral	4", 19'	7	7	0.°5-1.°5	0."88-0."32	1."98 ± .12		Dyson
May 29	Sobral	8", 11'	16	6-12	0. 5-1. 5	0. 88-0. 30	0. 86 ± . 10		Eddington
	Principe	8", 11'	2*	5	0. 5-1. 5	0. 86-0. 30	1. 61 ± . 30		Davidson (Chant Young)
1922	Wallal	6", 10'	2	18	0. 5-2. 6	0. 85-0. 18	1. 74 ± . 30		(Dodwell Davidson)
Sept. 21	(Cordillo Downs)	3", 5'	2	14	0. 6-2. 9	0. 83-0. 16	1. 77 ± . 30		(Dodwell Davidson)
	Wallal	5", 15'	4	62-85	0. 5-3. 4	0. 85-0. 15	1. 72 ± . 11		
	Wallal	4", 5'	(3)*	135-139	0. 5-10. 4	0. 85-0. 04	-----		(Campbell Trumpler)

\* 4th plate not yet reduced.

### Prediction by Einstein's Theory $1''.75$

The agreement with prediction is especially good in connection with the 1922 eclipse. The last 4 plates, only 3 being reduced so far, were especially taken to test the 'distance law.' For this

purpose a wide-angle lens (of short focal length) was chosen giving a field of great range, recording stars at from  $5^{\circ}$  to  $10^{\circ}$  away from the Sun, by means which that law was also confirmed, the residuals, observation minus theory, coming out extremely small.

Third: We have pointed out in connection with a field of centrifugal force that a clock placed in such a field loses time. The same would be true if a clock were placed in a gravitational field. Now an atom is a periodic mechanism comparable to a clock. Its period would be greater in the gravitational field of the Sun than in that of the earth. As a consequence of this the spectral lines of a substance in the vapor envelope of the Sun would be shifted to the red as compared with the lines of the same substance produced on the earth. The relative displacement is about the same as that produced by a radial velocity of recession of 0.63 kilometers per second, being of the order of 0.008 Angstrom units measured in the region of  $\lambda=3883 \text{ \AA}$  lying almost within the errors of observations. Nevertheless the results of Evershed in 1918 and those of Grebe and Bachem in 1919 have offered considerable evidence in corroboration of the prediction; while at that time the findings of Prof. St. John of the Mt. Wilson solar laboratories were not confirmatory. In September 1923, however, in a paper read before the Astronomical Society of the Pacific he expressed himself as having come to the conclusion that he had confirmed the Einstein effect relating to the above shift of spectral lines; and that in the future a correction would have to be applied to spectroscopic measures.

At the last meeting of the National Academy of Science, (Science, May 16, '24) Prof. H. D. Curtis of Allegheny observatory reported recent measures of Drs. Burns and Meggers: "showing shift of lines very different from the simple and uniform amounts predicted by the relativity theory. Instead of all the lines being shifted by an equal amount to the red and that amount predicted by the Einstein theory, a very marked line-intensity factor is found. That is, for very faint solar lines there is little if any shift, and the amount of this shift increases as the wider and stronger lines are used." Then follow numerical results showing the above; and finally, after some further remarks along the same line, the following conclusion: "Accordingly the authors regard these results as a negation of one of the so-called proofs of the theory of relativity."

In the judgment of the writer the above statements are hardly conclusive. Similar findings were reported by Prof. St. John of Mt. Wilson in the *Astrophysical Journal* Vol. 41, p. 62, 1915. And Prof. St. John in a private communication to the writer says quite correctly: "Curtis' results showed the long recognized difficulty that strong (high-level) lines of iron show a shift to the red greater than the Einstein prediction, and the weak lines (low-level) a red displacement smaller than that required by relativity. This is at the center of the disk and the small differences from calculated values taken care of by radial currents of small cosmic velocities, upward near the photosphere and downward at very high levels. I see no way in the absence of pressure to account for these displacements without calling in relativity. At the edge of the disk the currents are no longer in the line of sight. The result at the limb is then a red displacement for both strong and weak lines of the full relativity value and a little more, this small excess being taken care of by differential scattering which produces a slight asymmetry on the red edge. There is no interpretation that will account for the red displacement at the limb, other than relativity."

These words coming from the greatest authority of solar spectroscopy in America and one of the greatest in the world, leaves hardly any doubt that also this last prediction has stood the experimental test of astrophysics.

The test of this prediction and a confirmative outcome is of especial importance for two reasons. The first is, that Einstein himself maintains that 'his whole theory of gravitation stands or falls by the success or failure of this test'; second that, as Eddington has pointed out, 'if the displacement of solar lines be confirmed, it will be the first experimental evidence that Relativity holds for quantum phenomena.'

Now a last word as to 'gravitation' itself. Newton assumed 'absolute space' and 'matter' essential and besides this the concept of force acting between any two portions of matter in space. He himself has said, that it is absurd to think of force acting between two bodies through empty space; but the inverse square-law works, to at least a very close degree of approximation, but it nevertheless remains 'unreasonable.' In Einstein's theory 'gravitational force' has no place as a fundamental concept! It is the 'gravitational field' analogous to the electrical and mag-

netic, or better, the 'electromagnetic field' that is the physical reality; and this finds its expression as a metric property of space; mathematically represented by a set of differential equations involving twenty functions which finding their place in these equations express the curvature of the space-time continuum just as the Riemann 'curvature components' do in three dimensional space. If these twenty functions were zero, either the gravitational field would not be present, according to Einstein, or it could be 'completely' removed by a proper change of frame of reference. But we know that it can not be removed except within a very small region. This means that there are some essential 'curvature components' that can not be done away with by any choice of frame of reference; in other words the twenty curvature components are not 'individually' equal to zero. Einstein now reasoned that there must be some mathematical relation corresponding to the physical properties of space-time independent of the choice of frame of reference; and here it is the genius of Einstein that makes the brilliant guess that certain 'linear functions' of these curvature components are zero outside of matter and equal to a similar group of functions within matter involving internal dynamical properties of matter itself, of which the electron theory will give us more and more information as time goes on.

The attempt has been made by Weyl and others to include the electro-magnetic field side by side with or intrinsically connected with the gravitational field, but Einstein says that such considerations will not bring us nearer to the true solution of the problem. According to him a theory in which the gravitational field and the electromagnetic field enter as an essential entity would be much more preferable.

Prof. Einstein has published a paper in the "Sitz. Ber. d. Preuss. Akad." 1923, in which he presents this master problem of "gravitation-cum-electro-magnetism" expressed in forty differential equations characteristic in containing besides the fundamental covariant tensor  $g_{\mu\nu}$  of the gravitational field the fundamental covariant tensor  $F_{\mu\nu}$  of the electromagnetic field, including of course also matter, as we usually do not think of it, namely as nuclei or centres of electromagnetic action; or electrons and protons exhibiting respectively negative and positive charges of electricity.

We may hope that also here experimental tests may present themselves that may bring us nearer to the goal of comprehending the true nature of matter and energy, or more likely the two as one, and that one would have to be energy.

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The author acknowledges as his principal source for the above the "Princeton Lectures" of Prof. Einstein, whose definitions will be recognized. The section on a rotating system of coordinates is taken from Prof Eddington's "Report."

## SOME PROBLEMS OF TAXONOMY

A. W. LINDSEY

During the past the pronounced tendency of systematists to do little more than describe and name different species of plants and animals was a prevalent and largely necessary evil. Even so, the work of taxonomists was indispensable in the biological sciences, and now that it is no longer without adequate foundations, it can be of inestimable value. Its value, of course, must depend to a high degree upon its usefulness to other branches of science, but if we except the field of medicine, none of the other branches have great intrinsic worth.

During the last thirty or forty years the classification of animals has been placed upon a sound phylogenetic basis which renders the work of a thorough systematist of the present day of much greater importance than the mere description and naming of species. Account must now be taken of the morphology, ecology and physiology of organisms, of paleontology where it serves, and possibly of genetics. The discoveries of geneticists, so far, appeal to the writer as incapable of wide application to the problems of taxonomy, although they may easily furnish many checks on the relationships of species and their subdivisions. The modern systematist must be well grounded in all branches of biology, and his work, in order to be reasonably accurate and useful, must express the deductions of such training.

The dignity of taxonomy as it should be, then, is scarcely to be denied, but it is all too true that many taxonomic works of the present afford more than one opening for criticism. As a systematic entomologist and a devotee of the Order Lepidoptera, the writer has noted with many misgivings certain phases of this matter which it is his purpose to discuss in this paper. Most important of these is the limitation of systematic divisions below the genus, including the questionable practice of naming slight variations. Closely related to this topic are the conflicting methods of naming such divisions, and last of all, one of the most vexatious questions in the classification of animals is that of the stabilization of generic names.

### I. The Species Concept.

The question of the existence or non-existence of species in nature is one of such age that some hesitation must be felt in attacking it. However, no discussion with which the writer is familiar furnishes a satisfactory foundation for a practical system of classification. All treat the species as a thing capable of rigid definition, either actual or imaginary, and herein their weakness seems to lie. In entering upon a discussion of this point it will be well to consider some of the material which it concerns.

In the insects, and in the Lepidoptera perhaps as much as in any other order, we are dealing with a highly successful group which has ramified considerably in adapting itself to various conditions of environment, yet still includes relatively generalized forms. These are capable of becoming modified further in response to changes of the habitats which they now occupy. As extreme examples of the specialized types, *Feniseca tarquinius* Fab. and the myrmecophilous Lycaenidae may be cited among the Diurnals. *Euxoa* among the moths and *Argynnis*, *Melitaea* and *Euphydryas* are good examples of the more generalized genera. It must be clearly understood that all of these forms are specialized in some degree, as, of course, all existing Metazoa are.

Such forms as *tarquinius* may be passed over briefly. It seems that everyone should agree in accepting them as well defined, natural units to which the designation species is properly applicable. In the writer's opinion there are many such species whose existence as natural entities cannot seriously be questioned. Powers applies this idea of species in a sweeping way. He states that "The whole spirit of modern biological research seems to the writer to demand the conception of species as realities,—not all alike, in their reality, of course."<sup>1</sup>

In contrast to this view, Montgomery says that "in Nature occur only individuals, as was clearly pointed out by Lamarek, and is generally acknowledged at the present time, species and other groups being arbitrary concepts."<sup>2</sup> By an extremely rigid and inclusive application of this view, it may possibly be regarded as

<sup>1</sup> Studies from the Zool. Lab., U. of Neb., no. 95. Reprinted from the *American Naturalist*, xliii, 1909.

<sup>2</sup> Montgomery, On Phylogenetic Classification, Proc. Acad. Nat. Sci. Phil. 1902, p. 193.

affecting all existing life, for the possibility of variation within some limit of degree and time is a fundamental provision of our theories of phylogeny. These facts, however, are axiomatic, *viz.*, that an organism's power to vary and to adapt itself to change of environment decreases with every progression, in whatever direction, from the primitive condition of its ancestors, and that there is an ultimate point beyond which the process of its evolution cannot go. That such a point exists, a point at which the species itself enters a state of senility wherein any considerable demand for further adaptation can result only in extinction, is abundantly proved by the dinosaurs, pterodactyls, and other extinct forms of the past. Among existing animals such forms as the birds of paradise and the head fishes appear to be senile to an appreciable degree, and less conspicuous examples are found in the Lepidoptera already mentioned. Such forms may easily be recognized as natural entities.

For the purposes of a practical system of classification it is necessary to reach some basic idea of our unit and the way that it is to be applied, and this idea must necessarily be applicable to the entire subkingdom, if not to all living organisms. Many of the so-called species of the present are in a state of senility as pointed out, some are primitive but constant, while others are either primitive or generalized, and very actively variable. It is obvious both from past experience and from a logical consideration of these facts, that the application of a single rigid concept to the limitation of all of these groups is a difficult task. Here the neglected element of time enters. Combined with senility, it furnishes us with an ideal of the species as a natural unit which we may define as follows: *A group of individuals may exist as a natural entity at any period of time in the phylogeny of the line to which it belongs when the specialization of this group has proceeded to such a point as to preclude (a) the production of a marked degree of future modification and (b) discernible intergradation with other similar units, and in this state may be regarded as an ideal species.*

After the elimination of such forms there remains the immense number of living organisms which are not, at present, divided into rigidly delimitable species. Perhaps after the passage of many thousands of years these will have resolved themselves into such species as were defined in the last paragraph, but here again time is the important factor. These variable groups must

be treated as they are at present, and together with groups of all other degrees of stability. The transition is so gradual that different terms cannot be used to designate conveniently the various conditions, therefore it becomes necessary to arrive at an accurate idea of the variable application of that now in use, namely, species. Since, in a consideration of phylogeny, the present must necessarily refer to geologic time, the result may well apply to all scientific results of the past, and to the future beyond logical prediction.

In order to be compatible with the ideal species, "species" selected from the more variable forms should be *definitely delimitable groups of individuals, regardless of the amount of variation included*. This is essentially the idea of Powers<sup>1</sup>. Montgomery expresses a very convenient idea of species, although with a very different intent, which may be used in this connection. This is found in his definition of a species as a "mental section of a line of evolution."<sup>2</sup> The opinion has already been expressed that these sections may be natural entities, and that in order to be properly regarded as species, they must be. In other words, in an hypothetical cross section of the phylogeny of all existing forms, the species are those elements which are definitely separable. When elements named as species in the past are found incapable of separation, they must be regarded as divisions inferior to the species of this interpretation, and the species to which they belong should be sought in a "section" of greater extent. The accurate arrangement of any of these elements in our actual classification is, of course, fraught with considerable difficulty. Until our knowledge is more nearly complete and perfect we must expect constantly to revise our results; the careful and diligent study of an abundance of material—ideal conditions, to be sure,—may some day result in a classification of reasonable stability.

It is not the writer's purpose to present here a discussion of the problems of transmutation of species,<sup>4</sup> the influence of genetics on the species concept<sup>5</sup> or the methods of limitation of species,<sup>6</sup> which are taken up in the papers cited. It is proposed to suggest in this concept of species a basis for practical classification. By reducing the application of the term species to groups

<sup>3</sup> Montgomery, *op. cit.*, p. 206.

<sup>4</sup> Powers, *op. cit.*

<sup>5</sup> Davis, Species, Pure and Impure, *Science* lv, no. 1414, pp. 107-114, 1922.

<sup>6</sup> Montgomery, *op. cit.*

of individuals which are at the present time delimitable, without regard for the extent of variation embraced by any one, it should be possible for the average worker, as well as the specialist with extensive resources, to become familiar with the chief units of any division. The next difficulty is the treatment of the subordinate divisions of such extremely variable species as some of those included in *Euxoa*. In discussing this, although a degree of unwelcome complexity is thus introduced into the second part of this paper, it will be convenient to take up in rather intimate association the methods of subspecific nomenclature and the value of the various subdivisions.

## II. Subspecific Divisions.

In the first topic of this paper the species concept was discussed, with the conclusion that the term species properly designates a natural entity consisting of a delimitable group of individuals. This was qualified by the addition of the element of time, recognizing that the species of the present are in varying stages of evolution, and that many of them may ultimately resolve themselves into more nearly ideal species. As the ideal species, senile forms which had run through their possible phylogenetic development were mentioned. The purpose of the second topic is the discussion of the subdivision of the more generalized and variable species of the present, and the nomenclature to be applied to their subordinate parts.

Formulating the problem as a generally applicable hypothesis, rather than as a specific case, let us consider the ways in which these variable groups have been treated. We may examine them as two hypothetical species, both variable. Each in its entirety may be regarded as a well defined "cross-section," the first made up of a number of fairly definite subordinate sections and the second of scarcely separable subordinate components. The two may be likened to a cellular tissue in comparison with a syncytium.

The first hypothesis finds many examples in existing species which occur in two or more forms, usually well marked. The early method of treating such species was to accept the form first named as the species and those discovered later as varieties. If an occasional specimen appeared showing a marked variation from the normal, it was, and still is, known as an aberration. Many of these bear names. This simple subdivision of species

was long accepted as sufficient, but increasing inquiry into phylogenetic relationships has shown that with such an arrangement forms of indubitably different value are often accorded the same rank.

Some writers deny the right of the original specific name to stand alone if any named variations exist.<sup>7</sup> This makes necessary the use of a trinomial for the correct designation of any form of a variable species. The following paragraph by Hartert, Jourdain, Ticehurst and Witherby<sup>8</sup> is pertinent in this connection: "As the use of trinomials for subspecies—or better, geographical or local races—does not seem to be generally understood, it may be here explained that when a species is divided into two or more races, or when two or more species are grouped as races of one species, then each of these races must have a trinomial appellation. It is impossible to say which is the oldest or parent form, therefore the first named race of all those grouped under one species is arbitrarily taken as the typical race, and its name becomes that of the species."

Other writers have adopted a very logically conceived division of the variations into forms and geographical races, a method of subdivision which was very successfully employed in the most recent check list of North American Lepidoptera.<sup>9</sup> In this list Dr. McDunnough also drew on the work of Mr. Roger Verity<sup>10</sup> for another form of subdivision, the seasonal generation, exemplified in *Pieris napi* Linn. This species is listed in our fauna with seven races, two of which are accompanied by named aestival generations, and in addition to these seven, three vernal generations with accompanying aestival generations. According to the lettering used, the vernal generations are ranked with the races. This method of division, though it undoubtedly has its faults, appears to be by far the most accurate indication of phylogenetic relationships yet devised for expression in a linear series. We must recognize the existence of geographical races, of which an excellent example, based largely on genitalic structure, is found in *Hesperia tessellata* race *occidentalis* Skinner.<sup>11</sup> Likewise the existence of seasonal generations has been proved beyond doubt,

<sup>7</sup> In Lepidoptera, see Rothschild & Jordan, Revision of the Sphingidae.

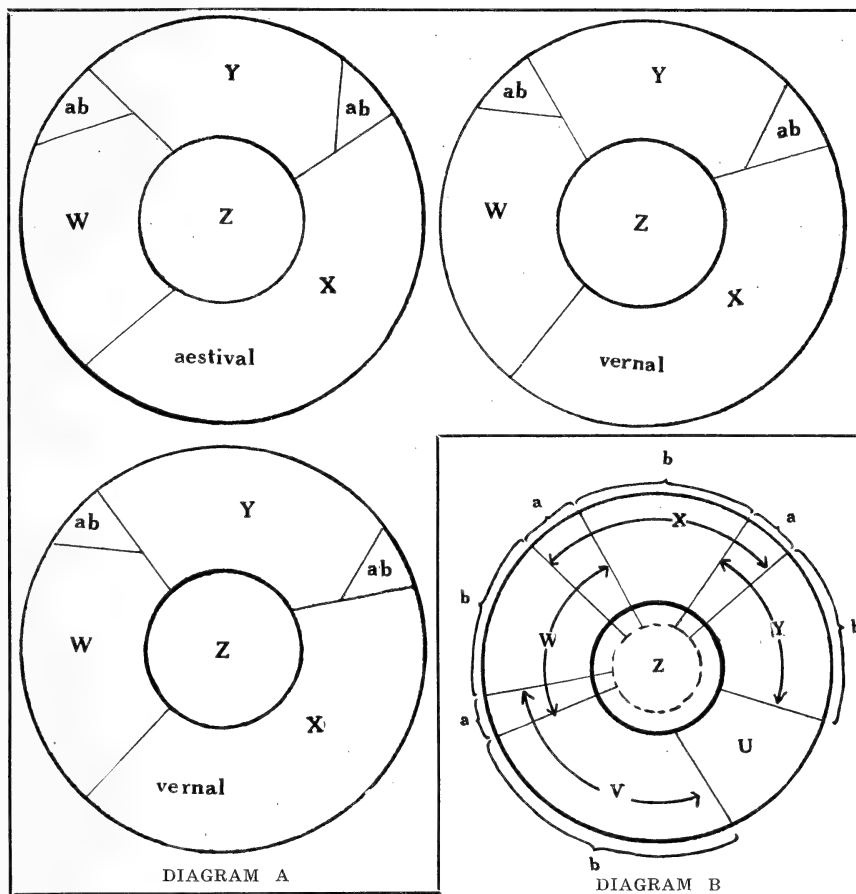
<sup>8</sup> A Hand-List of British Birds, pp. ix-x, 1912.

<sup>9</sup> Barnes & McDunnough, Check List of the Lepidoptera of Boreal America, 1917.

<sup>10</sup> Verity, Rhopalocera Palearctica.

<sup>11</sup> Barnes & Lindsey, *Ent. News* xxxii, 79-80, 1921.

most conspicuously in the Indian fauna of the wet and dry seasons, but quite evidently in the various forms of *P. napi* Linn. Aberrations are known to every systematist and the name is self explanatory. Varieties have been confusing in that the term has been made to include everything not nimotypical. In the check list mentioned the terms form and race have been substituted for



variety. A form is regarded as a variation occurring side by side with the nimotypical form, in contrast with geographical races, which are variations occurring in a region distinct from that occupied by the nimotypical form. This substitution seems to be so successful that it permits the discarding of variety as an obsolete term. In order to present the consideration of these subdivisions more graphically I have drawn diagram A, assuming

for its basis an hypothetical species showing all of the variations in question. This might well be regarded as a part of the evidence furnished by *P. napi*, but introduces elements not observed in that species.

In this diagram the three circles represent three hypothetical cross sections of the species, each of which may be regarded as a somatic generation. The central element in each of these may represent the basic form of the species, and may, for convenience, also be regarded as nimotypical. The axial line through the three z elements represents the main line of the germplasm, although the complete connection of the three generations must necessarily be regarded as the cylinder of which they are cross sections. That part of the three generations not included in the nimotypical form is divided into a geographical race w, a form y, and a third element, x, including alternating vernal and aestival generations. W and x are assumed to show aberrations. In the natural state, the probability is that w would produce only w, although the available evidence suggests that artificial change of environment would lead to the production of each from the other. Y and z, occurring in the same region, would be produced from each other. As worked out by Verity in *P. napi*, x may represent a definite line.

Designating the genus as G, trinomial nomenclature would name these forms Gzz, Gzx, Gzy and Gzw. In the case of the second a puzzling situation presents itself. We have already chosen to apply to the entire species the name which has priority. If we continue this by assigning to one of the seasonal forms priority over the other, a complete designation of the latter involves the use of a cumbersome quadrinomial, and any minor variation which might receive a name would carry it one step further. Another difficulty with such a species is that a thorough analysis may give us a series of aberrations, such as Gzw ab. and Gzy ab., which are distinguished at least in part by the same characters and named only upon a basis of their origin. This is not common, of course, but in the insects is by no means hypothetical.<sup>12</sup> Can it possibly be regarded as necessary for the purposes of classification to toil with such a series of names? No matter whether such an aberration is among the progeny of w, or y, it is the product of the same germ plasm, apparently in

<sup>12</sup> Reiff, *The Lepidopterist* i, 15, 1916. Dyar, *The Lep.* i, 31, 1917.

response to the same stimuli, and as such may be designated by reference directly to the nimotypical form with at least sufficient minuteness for ordinary use. For genetic considerations these minor forms may be treated without naming, as will be mentioned later. We should note, before leaving this matter, that in most cases such divisions as have been discussed are based upon differences of color and pattern, which are apparently quite directly responsive to changes of environmental conditions. When lines such as w, x and y occur, their existence is probably due to slight normal differences of environment, and we must recognize that the fluctuations of meteorological conditions might easily result in temporary similarity of these normally different conditions of existence, such as would produce forms and aberrations like those under discussion.<sup>13</sup> If the similarity of these is complete, they may certainly be named as one; if partial, as in the case of the *Catocala amica* forms mentioned in the paper last referred to,<sup>12</sup> they are certainly not worth separating from their parent forms.

The problem presented by this type of variation, involving only a moderate number of forms in any species, and these fairly well marked, is comparatively simple. It is essential, in the first place, to have a name which may be applied definitely to the entire species, and there is no serious objection to the rule of priority now applied. In a few cases, as *Papilio glaucus* Linn., a subordinate form has priority. When, as in this case, the nimotypical form occurs in only one sex, the necessity for modification is strongly suggested, but the simple application of trinomial nomenclature is an ample measure.

With regard to the use of polynomials to indicate the complete relationship of the ultimate division with the nimotypical form, personal opinion must enter. As matters stand at present this unavoidably leads to cumbersome combinations. Neither modern system of nomenclature eliminates these, yet these systems have points of value which we should be reluctant to sacrifice. If the pronounced tendency were not present among entomologists—I feel inclined to say lepidopterists in particular—to

<sup>13</sup> In dealing with such superficial characters as distinguish most minor forms and aberrations, the question of reversal can hardly enter. More fundamental modifications such as would involve this question do not, in any case known to the writer, furnish the basis for such a complexity of nomenclature as is here discussed.

name the most minute variations, I should favor the use in this field of a combination of the trinomial method with the subdivisions of Barnes and McDunnough's Check List, but because of the existing tendency, such a course seems to defeat the object of systematic science. What is the use of a named race, form or aberration which is so rare or so obscure that only a few specialists in the country can determine it? Such fine ramifications can be traced out without the application of names, if, indeed, they are worthy of notice, and the studies recorded still be made available to the few who will carry them on. The names applied to minor forms are usually an inert encumbrance of the nomenclature, at the best, and are a hindrance to many in a branch of science which should be efficiently helpful to all.

This brings us to the question of the actual value of variations. I think that no one will fail to agree that such a conspicuous thing as *Vanessa antiopa* ab. *hygiea* Heyd. is worthy of a name, or that *Poanes hobomok* ♀ form *pocahontas* Scud. is quite distinct from the normal female and worthy of independent designation. In the later, however, there has recently appeared another named division, *Poanes hobomok* ♀ form *pocahontas* ab. *friedlei* Watson.<sup>14</sup> Some of our leading lepidopterists have been guilty of actions almost as objectionable, but in this case a serious weakness is found in the fact that the unique type was reared under artificial conditions. The type itself is described as an abnormally dark *pocahontas* with reduced maculation—characters which go hand in hand in the *Hesperiiidae*. It was reared with one other specimen, a male, which is also noted as exceptionally dark. Add to this the fact that the conditions of rearing might reasonably be expected to favor melanism, and no conclusion seems possible save that the name is utterly useless. In my series of thirty or forty specimens of *hobomok* I have traced a gradual transition from the normal female to very dark melanic forms in which three or four stages equal in value to *friedlei* can be distinguished. What possible good could come of naming them?

No doubt many names such as that discussed in the last paragraph are applied by men who have too little material for a proper appreciation of the general characteristics of a species. Diagram B will serve to illustrate our consideration of this prob-

<sup>14</sup> Watson, *Jn. N. Y. Ent. Soc.* xxviii, 232, 1920.

lem, which is intimately associated with the second of our hypothetical species. However, it might well be based on such a species as *Euxoa tessellata* Harris or *E. messoria* Harris. The entire diagram represents the hypothetical cross section, the species under consideration. Z, the inner circle enclosed by an unbroken line, may again be taken as the basic and nymotypical form, overlapped as represented by the dotted circle, by each of the variations v, w, x and y. These variations, whether races or forms, may also overlap each other as shown. Obviously, to a man possessing series or specimens only from the sections b of these variations, they would seem abundantly distinct and deserving of names. By supplementing this material with other specimens from the a zones he would at once perceive their intergradation and the necessity for great circumspection in their treatment. Such variations appear to be incipient forms, possibly incipient species, but at such an early stage in their evolution that their right even to be named may be seriously questioned. All belong to species z, and to any but a laboratory scientist or a student of heredity the simple binomial Ga would be much more useful than a long series of named, intergrading forms. The work done in late years on heredity in *Drosophila* is an excellent case in point.<sup>15</sup> What a galaxy of named *Drosophila* forms we should have if the geneticists showed the same tendencies as some of our systematists! Another unfortunate feature of such species is that they may produce a distinct form such as u. The probable treatment of such a form would be assignment to a rank equal to that of v, w, x and y, although it alone might deserve to be called a form or race. I venture the assertion that many species of our present classification, at least in the order Lepidoptera, will fit more satisfactorily as subdivisions in such a classification as this than in their present arrangement. Mr. F. H. Benjamin has already done an excellent piece of work on this basis in the genus *Lampra* Hübner (*Rhynchagrotis* Smith).<sup>16</sup>

Although, as is natural, the foregoing considerations have been illustrated by mention of insects whose study gave rise to them, an attempt has been made to formulate them in such a general way that each individual may adapt them to his own fund of

<sup>15</sup> Morgan *et al.*, Mechanism of Mendelian Heredity, 1915, and other works.

<sup>16</sup> Benjamin, F. H., A Study of the Noctuid Moths of the Genera *Lampra* Hbn. and *Cryptocala* gen. nov., Bull. S. Cal. Acad. Sci. xx, part 3, 1921.

knowledge. They propose to show that the most satisfactory and accurate system—or systems—of nomenclature yet proposed has become a burdensome vehicle under present conditions,<sup>17</sup> but that this fault is due rather to the useless splitting of species into subdivisions of increasing minuteness than to any defect of the system itself. If only the workers who take delight in naming minute variations would curb this tendency or transfer their affections to other fields! Considering again the science of entomology, the biological and ecological study of insects supplies an inexhaustible and intensely interesting field. Moreover it is available on every hand, it does not require the formation of troublesome and expensive collections and libraries, and ones activities can be adapted to such apparatus as he can secure. It is essentially the field for the individual worker, wherein he may do accurate and valuable work if he only will.

### III. The Stabilization of Genera.

A very troublesome phase of systematic work is the instability of nomenclature. Three classes of names are involved. *viz.*, specific and minor, generic and subgeneric, and those of major divisions. The first have caused very little trouble, for the simple recognition of priority is the sole requirement of all taxonomists save a few classical purists. The last have also been the source of little dispute. Generic and subgeneric names, however, are the source of infinite difficulty, and offer a problem which seems little nearer to solution today than a decade ago.

When a writer, in describing a genus, fixes its type, no misinterpretation can be made save through the improper association of species, which is outside of the pale of nomenclature. When a genus is erected to contain a single species this logically becomes its type and the case is equally clear. It is the genera described before the necessity of type fixation was recognized, usually to include a motley aggregation of species, which cause so much trouble.

The difficulty of fixing the types of such genera has long been recognized, and several codes have been published for the direction of this work. Of these the writer feels competent to discuss only those for the use of entomologists, since it is with these

<sup>17</sup> I am indebted to my friend and colleague, Dr. T. C. Stephens, for the information that when the trinomial system was originated, this ultimate difficulty was suggested by British Ornithologists.

alone that he has had practical experience. The earliest which we need to consider is that of Walsingham and Durrant.<sup>18</sup> This code formulates the method of fixing the types of genera which was in common use until the present century, and appears still to be favored by some European scientists. The most important principle involved is its acceptance of restrictions. In all codes the first provision is that the type shall be selected from among the species originally included in the genus,<sup>19</sup> and this is the only restriction now generally accepted as affecting the fixation of the type. The rules formulated by Walsingham and Durrant, however, express the principle so widely followed in the past, providing that if any writer used the genus subsequent to its description, and eliminated part of the originally included species, the type must be selected from those of the originally included species which he retained in the genus. In some cases this may be very reasonably applied, but it is weak, and hence scarcely to be considered as a generally applicable rule for the following reasons: First, in the early days of entomology, works covering the entire animal kingdom, yet of some scientific pretension, were often published. Obviously such works could not attempt to mention every known species unless they were purely systematic, hence only a few, or even one, was mentioned as an example of each genus. No intention of the writer to restrict the genera by such means can reasonably be assumed, yet such a citation of a single species in illustration of a genus has been taken as a valid fixation of the type. A good example is the genus *Hesperia* Fab. This genus originally included all of the Lycaenidae and HesperIIDae. Cuvier mentioned it, citing *malvae* Linn. alone as an example.<sup>20</sup> It is argued by some writers that this action fixes the type, but it is quite clear that the inclusion of this particular species was incidental. Thirty-nine years later another work of Cuvier made the same citation, with a footnote which indicates that his use of *Hesperia* was intended to be identical with that of Fabricius.<sup>21</sup> A second weakness with these restrictions is that they may be due to the fact that the restricting work dealt with only a limited fauna, or a certain collection, as in the case of

<sup>18</sup> Lord Walsingham and J. Hartley Durrant, *Rules for the Regulation of Nomenclature*, London, 1896.

<sup>19</sup> The International Rules provide also for the designation of types of genera originally described without included species.

<sup>20</sup> Cuvier, *Tabl. Elem.* 592, 1798. *Fide* Scudder.

<sup>21</sup> Cuvier, *Animal Kingdom* iv, 285, 1837.

Stephens' treatment of *Nisoniades* Hbn.<sup>22</sup> Scudder cast out Stephens' citation of *tages* alone under this genus for other reasons.<sup>23</sup> The one commendable feature of this rule is exemplified by the history of *Polyommatus* Latr. It seems reasonable that an author's modification of his own genus, especially when he treats all of the species concerned, should be recognized even without actual citation of a type. The difficulty here lies in impossibility of drawing the line at all if we wish to admit some restrictions, and if we admit all, it is impossible ever to predict the stability of the nomenclature. At any time some obscure work of no great value may be brought forward to play havoc with current usage.

The second code is that published by Banks and Caudell.<sup>24</sup> It is an admirably worded, clear and concise series of rules, and I am aware of but one objection to it, *viz.*, that it permits a species to be the type of only one genus, unless, of course, it should become the orthotype of a second through oversight. This is inately weak in that it robs actual type citations of their concrete value. Under such a rule the citation of the type is useless without a reasonable degree of certainty that it has not previously been cited as the type of another genus. The most important objection to this rule, perhaps, is that it conflicts directly with the International Rules.

These, the International Rules of Zoological Nomenclature, are the code which has by all means the best claim to the consideration of Zoologists. They were formulated by a committee of the International Congress of Zoologists, supposed to be representative of the various opinions obtaining on the subject of nomenclature in scientific circles. The rules are supposed to arbitrate differences of opinion and to arrive at the solution of greatest fairness to all concerned. One of our leading lepidopterists objects to following them on the ground that the congress was not truly representative, and that, in his opinion, certain type fixations not in accord with the rules are perfectly valid. An authority on another order of insects insists that Lamarck<sup>25</sup> did exactly the same thing as Latreille<sup>26</sup> in citing examples of genera, and that his citations should be regarded as valid type fixations, even though he did not use the word type. True enough, but this

<sup>22</sup> Stephens, Cat. Brit. Lep. 22, 1850.

<sup>23</sup> Scudder, Historical Sketch 228, 1875.

<sup>24</sup> Banks, N., and Caudell, A. N., The Entomological Code, 1912.

<sup>25</sup> Lamarck, Syst. An. sans Vert., 1801.

<sup>26</sup> Latreille, Consid. Gen., 1810.

is the very point on which it is necessary to have some authority such as the rules for a dependable common basis. The trouble through all the years has been just that which is made by these objections, namely that every systematist has some favorite opinion to which he holds like grim death in the face of all opposition. Perhaps the writer too has favorite theories, and is championing them as radically by supporting the International Rules, but since this support occasions some extreme modifications of his own wishes in the matter of nomenclature, it can hardly be classed with the opinions here mentioned.

The desire to make exceptions is also displayed by even so great an authority as Dr. Handlirsch.<sup>27</sup> In his considerations of "Nomenklatur, Typen und Zitate," this writer formulates a series of rules of nomenclature drawn from various sources. He uses the International Rules for the fixation of genotypes, but in connection with his rule eight on priority, taken from the same source, proposes the following exceptions: "Ausgenommen von Umstossung auf Grund der Prioritätsregel sind nur solche Namen die ganz allgemein bekannt und in vielen Hand— und Lehrbüchern eingebürgert oder medizinisch, technisch bzw. ökonomisch von Bedeutung sind, sowie solche, auf Grund deren ein allgemein gebräuchlicher Name höherer Kategorien errichtet wurde, so dass durch Ungültigkeitserklärung des einen Namens auch die anderen umgestossen werden müssten." This is a component of the International Botanical Rules. It seems utterly impossible for such a rule to produce a uniform result in the hands of all systematists. Who shall say what degree of familiarity constitutes this right to stand? Moreover, what if a few usages do have to be changed? Many now common were made to supplant others of a more logical nature years ago, when the older usages had stood for decades. For example, *comma* was cited as the type of *Hesperia* by Dalman in 1816 (*fide* Scudder), and the genus was used in this sense by competent writers as late as 1883, only to be removed at last to the place which it has since occupied with *malvae* as the accepted type.

As the International Rules stand, they are a satisfactory working basis for the stabilization of nomenclature, and should not be radically changed. By denying the use of the so-called restrictions, and by accepting as the type of a genus the first species

<sup>27</sup> Schröder, Handbuch der Entomologie iii, 83, 1913.

actually designated by the word type or an equivalent of unmistakable meaning, whether or not it is already the type of another genus, they make it possible to eliminate much historical work in fixing genotypes, and to arrive at a definite result with the greatest possible degree of certainty that no pertinent matter has been overlooked. The chief source of trouble in the rules seems to be the arbitrary limitation of valid type fixations to those in which the word type is used. Some argue that in French this word does not have the same meaning as in English, but according to all available dictionaries it has the proper meaning, among others, even as in English it may mean only a representative. Any objection to the use of these rules, however, is weak. Its purpose must ever be the preservation of some familiar use of terms, and *no system can be applied to zoological nomenclature as a whole which will not overthrow some such usage*. Moreover some arbitrary rule is necessary, advanced and supported by authority, to override the multitude of personal opinions which will otherwise never find a common ground. Nomenclatorial research is a fascinating pursuit, but it cannot be said to advance scientific knowledge an inch. It should be settled definitely for all time, and the writer does not hesitate to express his opinion that those who oppose the use of the International Rules are acting selfishly and against the interests of the science which they pretend to serve.

I feel these things very deeply. In common with many other systematists, I have spent a considerable amount of time during five or more years to reduce the described genera of my favorite group to a definite basis. In view of some correspondence which has reached me recently and has brought my interest in the matter up to its present pitch, I cannot but feel that such efforts are, at least for the present, wasted. These genera have never been consistently worked over. It would be relatively simple to fix the type of each by the International Rules, but what would be gained if Richard Roe should insist that he could not accept certain results, and John Doe that certain others are against his beliefs? The result does not hinder their work, for in order to object intelligently they must understand all phases of the points involved. The greatest difficulty accrues to those who are not students of nomenclature, perhaps even indifferent systematists. In other words, by insisting upon points of personal opinion in matters which are not vital, the systematist hinders him whom he

would help, to whom a real and conclusive stabilization of nomenclature would be invaluable.

We have the International Rules. They are clear and applicable, and with the settlement of European difficulties it should be possible to arbitrate properly the few doubtful points which may arise. Why should not every systematist suppress his personal desires, accept the few changes which result from the use of the rules, and establish for all time this important, but none the less accessory, framework of science?

NOTE: This paper was written in the winter of 1921-22, revised and placed essentially in its present form in the Fall of 1922, and brought out again in the early Spring of 1924. On the eve of its publication the writer's attention was caught by an article by Professor E. B. Babcock,<sup>28</sup> a botanist, in which reference was made to Hall and Clements' "Phylogenetic Method in Taxonomy,"<sup>29</sup> The striking degree of agreement between the views expressed in the latter paper and in the preceding pages, where they touch upon the same subjects, is such as to compel its mention here. It seems that both botanists and zoologists are agreed upon the requirements of this branch of science, and we may hope that the future will extend the valuable renovation of methods which the present has begun.

<sup>28</sup> Babcock, E. B., Genetics and Plant Taxonomy, Science LIX, 327, 1924.

<sup>29</sup> Hall, H. M. and Clements, F. E., The Phylogenetic Method in Taxonomy, Carnegie Inst. of Washington, Publication No. 326, 1923.



# NOTES ON THE GEOLOGY OF GILES COUNTY, VIRGINIA

By \*GEORGE D. HUBBARD and †CAREY G. CRONEIS

## INTRODUCTION

### Location and Extent of Area

Giles County is in the northern section of the southwestern portion of the State of Virginia. It is bounded on the north by the State of West Virginia, on the east by Craig County, on the south by Montgomery and Pulaski counties, and on the west by Bland County. Pearisburg, the county seat, which lies a little north and west of the geographical center, is  $37^{\circ}19'N$  latitude and  $80^{\circ}44'W$  longitude.

Inclosed within the irregular boundaries of the county are a trifle less than 350 square miles.

### Previous Work

In 1881, Boyd<sup>1</sup> published his "Resources of Southwest Virginia," which contained, among other things, a short account of the geology of Giles County. Boyd, however, had merely summarized the also short account which appeared in W. B. Roger's "Geology of the Virginias" in 1841. The work, excellent for having been done in the early forties, was not so good forty years later. Boyd also gives a rather complete account of the county's mineral resources. Here it may be said that Mr. Boyd was an optimist when he was discussing the iron ores of Giles County. However, it should be added that he was also something of a prophet when he was discussing manganese prospects. Of this more will be said in the chapter on Economic Resources.

Stevenson,<sup>2</sup> in 1887, made a geological reconnaissance of a half a dozen counties in the southwest portion of Virginia. Giles was one of the counties visited and Stevenson's observations on

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<sup>1</sup> Boyd, C. R., "Resources of Southwest Virginia," J. Wiley & Sons, 1881.

<sup>2</sup> Stevenson, J. J., "A Geological Reconnaissance of Bland, Giles, Wythe and portions of Pulaski and Montgomery Counties of Virginia." Proc. of Amer. Phil. Soc., Vol. 24, 1887.

it were very good, considering the short time spent in the area. To quote the author, "The examination of the area under consideration was purely a reconnaissance, and the notes in several localities must be regarded as little more than suggestions to the one who may make the detailed study on behalf of the U. S. G. S." Stevenson, who was at the time Professor of Geology at the College of the City of New York, was a keen observer, and his work is not without value even today. A geological map accompanying the report, while recognizing but few divisions, is fairly accurate over wide areas.

In addition to the above mentioned work, the U. S. G. S. in 1884-7 made a reconnaissance map of the Dublin, Virginia-West Virginia quadrangle, in which is contained the greater part of Giles County. On this map, elevations are found to be very good, but no depression contour appears on the Dublin sheet, although there are many sinks in the county whose depth is close to 150 feet. However, everything considered, this topographic map is extraordinarily good for reconnaissance work. It was used, with corrections and modernization, as the base for the geologic map accompanying this report.

In 1907, Watson<sup>3</sup> published his "Mineral Resources of Virginia," which mentions the iron mines of the county, as well as the possibilities for the manufacture of cement.

Two years later, in 1909, there appeared Bassler's<sup>4</sup> "Cement Resources of Virginia." In this volume the stratigraphy of southwest Virginia is worked out in some detail. Giles County receives its share of attention, but post-Ordovician formations here, as elsewhere in the work, are slighted since they are not potential cement horizons. However, the writers have found this bulletin to be the very best of any of the meager sources of information on the Geology of Giles County.

Stose and Miser,<sup>5</sup> in their bulletin on the "Manganese Deposits of Western Virginia," which was published in 1922, give a complete account of the prospects in the county under discussion. Physiographic forms, stratigraphy, and geography of western

<sup>3</sup> Watson, T. L., "Mineral Resources of Virginia," Jamestown Exposition Commission, 1907.

<sup>4</sup> Bassler, R. S., "Cement Resources of Virginia," Bulletin 2A of the Virginia Geol. Survey, 1909.

<sup>5</sup> Stose, G. W. and Miser, H. D., "Manganese Deposits of Western Virginia," Bulletin 23 of the Virginia Geol. Survey, 1922.

Virginia are also discussed briefly in this bulletin, which has been used rather freely by the writers.

The above list completes the published references to the geology of Giles County. In addition, however, Watson has published a geological map of the state of Virginia. The geology of Giles County, on this map, is simply represented by five large divisions, whose boundaries are not extremely accurate.

### METHOD OF WORK AND ACKNOWLEDGMENTS

Field parties of students gathered from various colleges and universities have for some time worked in this region as a part of the Oberlin College Summer Session. The work was started in 1908 in Bland County and since that date nine other parties have studied in the region, and eight of these in Giles County itself. The camp from which the work was done has been each year in a new place so that a considerable part of the county has now been worked. Over 75 students have contributed to the solution of the geologic problems of the area. During each of these years a portion of the geologic section has been measured and described in detail, and this description has been handed on to the next class, so that a considerable heritage has accumulated.

In like manner collections of rocks and fossils have been made and added to the collections of former classes. Lists of characteristic fossils have thus been built up for several formations and for a larger number of members. No publications have ever come from this work but there is now a large body of data available for detailed study. It is hoped to put this material into shape for publication as special papers or topical studies, but first there seemed to be need for a general paper covering some such unit area as a county. Hence this paper has been prepared.

The sections recorded in the body of this paper are the accumulations of the several summers of work. Only a small percent was actually measured and described in any one year. Credit is due each class for its contribution to the whole. Credit should also be given Messrs. E. R. Smith of De Pauw University and C. W. Honess of Oklahoma University for special work on the fossils. They have spent a second summer collecting and have given much time to the study and identification of the various forms collected.

## TOPOGRAPHY

### Physiographic Location

The State of Virginia is divided into three physiographic provinces,\* which are named, from east to west, the Coastal Plain, the Piedmont Plateau, and the Appalachian Mountain divisions. The last named province is again divided into the Blue Ridge, Great Valley, and Alleghany Ridge regions. Giles County is included in the last named, or westernmost, of these divisions. The irregular valleys and ridges of Flat Top Mountain area are, however, more characteristic of the Cumberland Plateau region than of the Alleghany subdivision. On the other hand, East River, Wolf Creek, Sugar Run, Little and Big Walker mountains are typical zigzag or parallel eminences of the true Alleghany Ridges, defended by a strong sandstone.

Peters and East River mountains are the first westernmost ridges and mark the initial sharp upturning of the strata. To the northwest from these ranges is the much dissected, mature Alleghany Plateau region whose strata are nearly horizontal or very slightly flexed, but contain no true folds. However, a little south of the point where the New River enters West Virginia, the pronounced folding begins and, in a short distance, indeed in one formation (the Hinton), the dip increases from the horizontal to past the vertical.

### Relief and Drainage

The central portion of Giles County is a broad lowland, wherein flows New River, the master stream of the area. The western portion of the county is made up of irregular ridges and intermontane valleys. The eastern portion is much the same, except for the fact that the mountains here are consistently some 500 feet higher than those on the west. On the north, except where

\* Hayes, C. W., The Southern Appalachians. Nat. Geog. Mon. 1895, pp. 305-36.

Willis, Bailey, The Northern Appalachians. Nat. Geog. Mon. 1895, pp. 169-202.

Hayes, C. W. and Campbell, M. R., Geomorphology of S. Appalachians. Nat. Geog. Mon. 1894. pp. 63-126.

Bascom, F., Cycles of Erosion in Piedmont Province of Pennsylvania. Jour. Geol. vol. 29, pp. 540-559.

Campbell, R., Clapp, F. G. and Butts, Chas. U. S. G. S. Folio 189. Shaw, E. W., Bull. G. S. A. vol. 28. p. 128.

the small projection of Giles County extends into West Virginia, there is a natural boundary in the East River—Peters Mountain range, which is a somewhat uniform ridge approximately 3500 feet in height.

The southern boundary is, in the same manner, defined by a ridge running parallel to the mountains described above. This is the Walker-Gap Mountain range which is from 500 to 1000 feet lower than the East River—Peters range. A distance of 12 miles, on the average, separates the two ridges.

The highest point in the County is Bald Knob, in the east-central mountain region, whose elevation is 4,348 feet. The point where New River enters West Virginia has, of course, the minimum height, which is 1472 feet. Giles County, then, presents a maximum relief of 2876 feet.

Johns Creek, a tributary of the James River, has its source on the upper eastern slopes of Salt Pond Mountain. The extreme eastern portion of the county, then, drains into the Atlantic by way of James River. The divide between the streams flowing to the Atlantic and those tributary to the Mississippi system, may be drawn in Giles County along the crest of Salt Pond and Johns Creek mountains. This entire basin, however, does not comprise more than eight square miles so that, for practical purposes, it might be said that the county was drained by New River and its tributaries.

New River rises near Blowing Rock, N. C., and flows northeast to Radford, Virginia, a distance of about 100 miles. Here, it turns to the northwest and cuts through the mountains of Virginia and West Virginia to join the Ohio at Point Pleasant where it is called the Kanawha (as it is throughout its lower course). This system is, of course, antecedent to the uplifts and crustal movements which developed the Peters and Walker mountains. In fact, New River is the only one which has, in the Appalachians, preserved its Cretaceous or pre-Cretaceous course to the westward. This has been due, in large part at least, to differential warping which raised the headwaters so high that enough gradient was developed to enable the river to cut through the hard sandstones of the Walker and Peters ridges. These were elevated with the rest of the region, but slowly enough so that the river could maintain its course in spite of the elevation.

From Angels Rest, or Bald Knob, New River Valley looks

much like a great amphitheatre, which is walled in at all sides except where the stream enters and leaves the county. The entrance is by way of a narrow valley which is cut across the Walker-Gap Mountain ridge. The exit is by a similar valley, even more restricted, cut in the East River-Peters Mountain system. The principal tributaries to the New in Giles County are Walker, Wolf, and Sinking creeks. All of these streams, however, have their sources outside the county. East River, which has its headwaters in Virginia, flows, through most of its course, in West Virginia only to enter the New by way of Giles County. However, since it flows less than a mile in the County, the portion it drains is negligible.

The relative absence of small tributaries is a feature which is apparent at once. Streams which are carrying considerable water in their upper valleys are much restricted in size, when they enter the limestone area adjacent to the New River. This is due to the large amount of drainage which is under ground in Giles County, and of which more will be said later.

### Erosion Cycles

In Giles County, the elevation of the highest peneplain cannot be determined accurately because, having suffered the most from erosion, few of its remnants remain. In spite of this fact, Doe Mountain, Pearis Mountain, Angels Rest, and portions of the crest line of Peters and East River mountains have a fairly uniform height of 3500 feet. This elevation represents a former peneplain surface, which probably was completed in late Jurassic time. In this paper, this peneplain will be referred to as the Pearis Peneplain.† Above this early plain, which was then close to sea level there rose monadnocks to the height of 200 to 800 feet. Today Bald Knob, Butt Mountain, and portions of Sugar Run Mountain remain as remnants of these former elevations.

† Correlation in this paper is with Stose and Miser, who have given us one of the latest interpretations. It should be borne in mind that they assign earlier dates to most of the erosion plains than do Willis, Campbell and others; and also that Shaw has ascribed later dates than the older workers. In order to determine the dates of these peneplains it is necessary to trace them eastward and southward where they disappear under sediments of the Coastal Plain. Our work has never allowed us to carry forward such tracing hence we probably should not commit ourselves at all, and thus our correlations with the work of others in the Valley of Virginia and with Willis in the Northern Appalachians must be looked upon as provisional.

Brushy and Spruce Run mountains, as well as portions of Walker, Peters and Flat Top mountains have a height of approximately 3100 feet. This is the probable elevation representing a second base level which was only partially completed in Cretaceous time. This old base level will be referred to as the Spruce Run Peneplain.

A third and still less extensive base level was partially reached in early Tertiary time (probably late Eocene). This old surface is represented by heights in Buckeye Mountain, and by numerous spurs on all the mountains having the uniform height of about 2500 feet. This base level will be called the "Buckeye Peneplain" in this report.

A fourth, and last base level, which was in all probability reached in late Tertiary time, is represented by the numerous elevations in Giles County of approximately 2100 feet. This valley floor peneplain will be referred to as the "Pearisburg" base level. Remnants of this old surface are better developed in Monroe County to the north than they are in Giles, however, much of the land about Pearisburg and at various points along New River stand at this elevation. On this level are quantities of gravel, sands and clays of fluvial origin.

In latest Tertiary and in Quaternary time, New River has cut its present gorge in this area. Work towards the ultimate base level has scarce begun, yet the valley has been incised at least 400 feet. In the future, lateral planation will exceed vertical cutting in this county, because the New River is regulated by the natural quartzite dam across its valley at the Narrows. This resistant rock can be cut only very slowly, so that above the Narrows the limestone valley probably will continue to broaden rather rapidly.

The peneplain surfaces in Giles County are not so well defined as they might be, yet it is possible to make a rough correlation of the base levels recognized here with those described by Stose and Miser<sup>6</sup> as occurring in the Valley of Virginia.

The Upper peneplain at 3500 feet is undoubtedly the same as the Summit Peneplain of Stose and Miser, at an elevation of 3000-3800 feet. This base level is regarded as older than the Kittatinny peneplain of Pennsylvania. The Spruce Run pene-

<sup>6</sup> Stose, G. W., and Miser, H. D., Va. Geol. Surv. Bull. 23. "Manganese Deposits of Western Virginia," 1922. pp. 20-22.

plain corresponds roughly to the Upland peneplain of Stose and the Kittatinny peneplain. The elevations grade from 3100 feet in Virginia to less than 2000 feet in Pennsylvania. The Intermediate peneplain, as described by Stose, is in Giles County developed as the Buckeye Peneplain, which here is some 250 feet higher than farther east. The Valley-floor base level of Stose, is the Pearisburg Peneplain of Giles County. Here it is 100-200 feet higher than it is to the east in the Valley of Virginia.

Since Jurassic time it is evident that Giles County has been elevated some 3000 feet. The most widespread peneplain was the first. The later ones were successively smaller and more incomplete. The present drainage is about 1500 feet above sea level. A peneplain this far from the sea would probably stand 300-400 feet above sea level.

### Underground Drainage

A very prominent feature of this area is the sink hole topography. As has been mentioned before, the U. S. G. S. map of 1884 does not indicate any depression contours. However, these sinks develop with considerable rapidity, some of the older natives recalling a half a dozen of ordinary size which have appeared during their life time. The writers do not from this intend to convey the idea that the sinks were too small to be mapped in 1884. Their omission from maps of this issue is regarded as the result of the reconnaissance nature of the mapping, or to the fact that, at that date, no depression contours were used on any maps.

Sinks are confined to the limestone areas of Giles County. So common are they, that they can be of use in determining the outcrop of the Shenandoah and Chickamauga formations, to which horizons they are limited. Caves are invariably found at the bottom of the sinks. The latter have been formed by the falling in of the roofs of solution passages, which ordinarily have formed along joint plains. Some of the caves are so extensive that it is possible to travel many hundreds of yards through their various passages.

In many cases, the surface drainage is in the reverse direction of the underground, so that when an entire series of sinks develop along prolonged joint planes (as they often do), the surface drainage is reversed. As a result of this underground

type of drainage, many great springs are found bordering the New River, and small tributaries are uncommon in the limestone areas. The New, itself, seems to vary greatly in size over small areas. The writers believe that this is due to the fact that, some of its water, at places, flows underground or in crevices for a distance, only to join the surface waters of New River again in the form of great springs, some of which may be hidden but many of which are visible. Of course solution topography and underground waterways could not be developed much below the water table.

No typical karst topography has developed in Giles County, but the sink hole areas are usually turned into grazing lands since the soil mantle is too thin to be easily cultivated.

## STRATIGRAPHIC GEOLOGY

### INTRODUCTION

In Professor W. B. Rogers' classification of the geological formations appearing west of the Blue Ridge in Virginia, fourteen groups of strata were given numbers, beginning with the oldest. His brother, Professor H. D. Rogers, divided the Paleozoic rocks of Pennsylvania into fifteen sets, "extending from the deposits which witnessed the very dawn of life upon the globe, to those which saw the close of the long American Paleozoic day." Thus the names of these formations were the various parts of the day, instead of the ordinary geographic terms used. Extremes, then, of his classification were Primal, signifying the dawn (that is, lower Cambrian), and Seral, meaning night (and corresponding to the coal-measures.) In the literature of Virginia, both systems have been used. A table is introduced here to show the relation between these classifications and the one now in use.

The rocks of Giles County comprise all of the divisions of the Paleozoic from lower Cambrian to the lower Carboniferous inclusive. No younger consolidated strata are found, but some Tertiary gravels are present, which may be the approximate equivalent of the so called "Orange Sand" found in the states further west. Limestones are quantitatively in predominance in Giles County, being especially well developed in the older Paleozoic divisions. Besides limestones, there are shales, cherts,

CORRELATION TABLE OF GEOLOGIC FORMATIONS OF WESTERN VIRGINIA

Era.	Period.	Virginia and Pennsylvania Report Numbers.	First Pennsylvania Report Names.
Paleozoic.....	Pennsylvanian	{ XIV XIII XII }	Seral.
	Mississippian { Upper Lower }	XI X	Umbral Vespertine
	Devonian { Upper Middle Lower }	{ IX VIII }	Ponent Vergent Cadent
		VII VI	Post-Meridian Meridian Pre-Meridian
	Silurian { Upper Middle Lower }	V V IV	Scalent Surgent Levant
	Ordovician { Upper Middle Lower }	III III II	Matinal Matinal Auroral
	Cambrian { Upper Middle Lower }	II II I	Auroral Auroral Primal

conglomerates, breccias and sandstones. The latter are sometimes metamorphosed partially into semi-quartzitic divisions.

Most of the ridges are capped by the Clinch sandstone, which is a very resistant division of the Silurian, while the valley floor is usually the Shenandoah Limestone. Outcrops are often decreased or made wider by the complex folding and faulting.

On the following page is a table of the formations found in Giles County.

## THE CAMBRIAN SYSTEM

### Introduction

The Cambrian of Giles County is made up of limestones and shales in the lowest division, and of limestone and dolomite in the upper portions. The Middle Cambrian time seems to have been one of erosion in this area, although the unconformity between the Lower Cambrian Russell and the Upper Cambrian Shenandoah is not marked. Deposition was continuous from Upper Cambrian on into Ordovician time, hence the great Cambro-Ordovician limestone series.

### The Russell Formation

The Russell Formation, composed of variegated shales, massive and impure limestones, takes its name from Russell County, Virginia, where it is found developed to its fullest extent. It is probably equivalent to Apison and Rome formations of Southern Tennessee.

In the Pearisburg section, it is brought in over a small area running with slight variation east and west through Bane, by the large anticline between Pearis and Walker mountains. In this exposure, it is non-fossiliferous but in some localities\* it carries the *Olenellus* fauna of Lower Cambrian time. The formation passes from medium bedded, resistant, blue gray, blotched, limestone at the base, through highly colored green and chocolate shales and intermediate limestone lenses and layers, to greenish and yellow shales, which, in some places, grade directly over into the Shenandoah formation but in other places are separated from it by several feet of white and gray calcareous shales.

Four small anticlines, the largest of which is approximately

\* Russell County, Virginia.

## NAMES OF FORMATIONS

Period	Names used in this Report	Rogers <sup>1</sup>	Stevenson <sup>2</sup>
MISSISSIPPIAN	Hinton formation	Greenbrier shale	XI Umbral shale
	Bluefield shale		XI
	Greenbrier limestone	Greenbrier limestone	XI Umbral limestone
	Pulaski shale	Not described	Not described
	Price sandstone	Montgomery grits	X Vespertine
DEVONIAN	Kimberling shale	Catskill	IX
		Chemung	VIII
		Portage	VIII
		Genesee	VIII
	Romney shale	Hamilton	VIII
		Marcellus	VIII
SILURIAN	Giles formation	Oriskany	VII
		Lower Helderberg	VI
	Rockwood formation	Clinton	V
	Clinch sandstone	Medina	IV Upper Medina
	Bays sandstone	Medina	IV Lower Medina
ORDOVICIAN	Sevier shale	Hudson River	III
	Moccasin limestone	Utica	III
	Chickamauga limestone	Trenton	III
		Chazy	II
	Shenandoah limestone	Levis	II
CAMBRIAN		Califerous	II
	Russell formation	Not described	? Knox shale

<sup>1</sup> "The Geology of the Virginias, 1884."<sup>2</sup> "A Geological Reconnaissance of Bland, Giles, Wyth, and Portions of Pulaski and Montgomery Counties, 1887."

1000 feet across, and numerous structures of a few feet each, mark the crest of the larger anticline and make measurements to determine the thickness of the Russell Formation highly unsatisfactory. The thickness, however, cannot be less than 300 nor more than 400 feet.

The formation clearly marks a transition period which may have introduced the time of erosion correlated with the lack of Middle Cambrian, and directly preceding the time of deeper seas prevalent during the formation of the Shenandoah Limestone. That the formation is a weak one is clearly shown by the numerous folds throughout the entire thickness, some of which do not appear at all in the adjacent Shenandoah. It disintegrates rapidly into a soil which is not as fertile as that resulting from the decomposition of the Chickamauga and Shenandoah Formations.

#### **The Russell Formation Subdivided<sup>7</sup>**

x. At the base of the Russell formation is a medium even-bedded limestone exposed along Walker Creek below Bane. It resembles the Shenandoah in some of its characteristics and is very different from the usual Russell. It runs under the typical Russell and is obviously older, but since its base is not exposed it may be a lens with more typical Russell underneath. For this reason this division is here called x and grouped under the heading of Russell. The color is blue to gray with red and purple lines and blotches which give the member a purple tinge. It is very hard and resistant because it is in part siliceous. Very fine crystalline to dense with weak irregular jointing. There are many branching calcite veins which are thin and thread-like in appearance. No chert nor fossils seen. Weathers dirty blue and black, rarely light blue. In the stream the red lines and blotches are emphasized by weathering so that the entire rock appears red. It is a ripple maker in the stream.

Thickness 80-100 feet +

##### **1. CHOCOLATE, GREEN, AND BLUE SHALES**

Medium to thick bedded shales with prominent cross-bedding and jointing in all directions. There are a few master joints. There are also sandstone and limestone lenses, the latter of which are dense blue layers six inches to two feet in thickness and

<sup>7</sup> In all the subdivisions, the numbering is from the bottom up.

many feet in breadth. The colors grade into each other both vertically and horizontally. Great blotches of green or red are common. Weathers rusty brown to black. No fossils were seen.

About 150 feet.

## 2. CALCAREOUS SHALES AND LIMESTONES (THE MIDDLE LIME)

This division is thin bedded for the most part but there is one layer about eighteen inches in thickness. In general, the colors are buff to blue in the limestones, and green to brown in the shales, the entire formation weathering a dark brown, except a light blue 4 inch limestone layer which becomes yellow to white. In some places, it is paper bedded; blue with delicate yellow layers alternating. There are calcite veins, and in a limestone lense-like layer, there are cavities partially filled with calcite crystals.

From 10 to 30 feet.

## 3. GREEN AND YELLOW SHALES

Calcareous to sandy, thin, red layers occur. The formation is thin bedded, and rather regularly jointed so as to break into blocks. Weathers yellow and brown and disintegrates more rapidly than division number one.

About 50 feet.

## 4. BLACK AND GRAY SHALES

These occur locally below the Shenandoah and probably belong to the Russell formation. The colors are black, gray to nearly white, weathering a dirty black to mud color. These shales are dry, fissile and non-fossiliferous. They may be erosion remnants.

Thickness 0-10 feet.

Besides the exposure at Bane, the Russell outcrops about a half mile farther down Walker Creek and is also exposed over a very limited area at the Norfolk and Western Railroad cut near Goodwins Ferry. (Not shown on the map)

Bassler<sup>s</sup> believes that the formation has a thickness of at least a thousand feet in the vicinity of Clinchport, Virginia. He says, "Although the major portion of the formation is of little value from an economic standpoint, the argillaceous shales of the upper division may prove of use for mixture with pure limestones in

<sup>s</sup> Bassler, R. S. "Cement Resources of Virginia", pp. 148.

the manufacture of cement." However, the great range in the composition of these shales as indicated by the following analysis, should lessen the possibilities in this respect.

### ANALYSIS OF THE RUSSELL SHALES

Vicinity of Clinchport

(J. H. Gibboney, Analyst)

	1	2
Insoluble .....	41.72	89.52
Alumina and iron oxide.....	5.68	7.22
Lime .....	17.32	0.42
Calcium carbonate .....	30.93	0.72
Magnesia .....	9.17	1.05
Magnesium carbonate .....	19.29	2.21

While these analyses were made from samples of the Russell formation from a different area than the one under consideration, they may serve to give some conception of the composition of these shales in Giles County.

This is the first time that the Russell has been reported from Giles County, the reason being that the formation weathers so rapidly that it quickly covers itself up. The exposures noted above were first found in recent road or railroad cuts.

### CAMBRO-ORDOVICIAN

#### The Shenandoah Limestone

The Shenandoah Limestone is a heavy bedded, gray blue, dolomitic, limestone near the top, grading downwards into a darker more sandy limestone at its base. It takes its name from the Shenandoah Valley where it outcrops very extensively. There is a breccia at its base in some places whose fragments are made up of bits of shales from the older Russell formation. In other localities, this formation has been subdivided into or corresponds with the Honaker Formation, the Knox Dolomite, and the Noli-chucky Shales. It probably corresponds, except for the upper portions, with the Beckett Gneiss of New England, the Potsdam Sandstone in New York, and the Stissing Slates, all of the Upper Cambrian. However, Beekmantown, and even Trenton fossils are occasionally found in the uppermost layers.

This limestone has a thickness of at least 5000 feet at places

and includes many shale and sandy lenses and partings. It is for the most part rather heavy bedded and dense, but includes such wide variations in its great thickness that it is hard to generalize. It carries a large amount of chert in lenses and in nodules, the chert being both light and black, but the light is in great preponderance and the black occurs only in the lower layers.

The formation is for the most part calcite veined, with calcite nodules and calcite-filled cavities numerous. Pyrite occurs in the shape of pyritohedrons, and limonite and hematite pseudomorphs after these crystals are not uncommon. Fossils are uncommon in the limestone but a few gastropods occur as well as other fossils too fragmentary to be recognized. However, in some places the chert is quite fossiliferous and gastropods, brachiopods, and sponges can be identified.

The rock usually weathers light and has an uneven to conchoidal fracture. Many layers are wave marked. The jointing is as a rule not pronounced; however, it is so good in the county road cut along Walker Creek between Bane and Staffordsville, that the joint planes are with difficulty distinguished from the bedding planes. Practically all the valley floors are made up of Shenandoah Limestone, and the white chert remaining after the limestone has disintegrated is found widely scattered.

The limestone is quarried in several places in this region and is used extensively for ballasting, for lime making and for building purposes. The soil resulting from its disintegration is rich and productive.

### **The Shenandoah Subdivided**

Section along the Virginian Railroad cut at  
the Narrows of the New River

1. Gray blue, fine grained, rather massive limestone, with shale partings of one to three inches. Flattened layers of black chert and a few small calcite veins. The limestone layers are from several inches to three feet in thickness. The formation weathers light buff to white, losing all the blue. The fracture is uneven to conchoidal with minor jointing vertical to the bedding planes. No fossils seen. Dolomitic. 25 feet.

2. A gray blue, fine grained, massive limestone with no chert, having, however, nodules and veins of calcite arranged in all

directions. The layers are two to six feet in thickness. About six feet from the base, there is a two foot layer which is considerably darker than the rest of the division. Weathers light buff to white but does not bring out the bedding. The fracture is conchoidal with coarse patterns. Joints are rare and small. No fossils seen. Dolomitic. 20 feet.

3. Color as in one and two—fine grained, crackled and hackly, siliceous limestone of 11 feet between a one foot layer of light cherty limestone at the base and a blue cherty layer of two feet at the top. Weathers black to buff. No fossils seen. No calcite veins and no chert in the middle portion. 14 feet.

4. Gray crystalline limestone layer with no apparent bedding. No chert. Joints intersect in all directions giving angular blocks of small size. Calcite nodules numerous and a little calcite along the joints. Weathers dark. No fossils seen. 10 feet.

5. Light siliceous limestone with veins and small nodules of calcite, also of quartz, and the entire division is sprinkled with quartz grains. This division is conspicuous as a light band across the face of the cliff as it weathers very light. There are disconnected delicate pink threads shot throughout the layer. 3 feet.

6. Dove colored, fine grained, dense, siliceous limestone with inconspicuous bedding. No chert, but with numerous calcite veins, some of which are in the joint planes. Calcite nodules and crystals give this division a mottled appearance. No fossils seen. 7 feet.

7. Bluish, massive, cherty, crystalline limestone, with round quartz veins and fragments of chert and chalcedony. The bedding is not apparent. Weathers brownish with ferruginous blotches. Crystals of light and dark calcite give a pronounced mottled appearance to some layers. Coarse, hackly fracture and little jointing; no fossils. 31 feet.

8. Bluish gray to drab, dense, fine grained, crystalline, uneven bedded limestone with calcite veins and bunches of calcite crystals. Fractures and weathers as No. 7. Joints are rare but when they do occur they are in all directions. This division seems to be a leveling up layer on a surface of marine erosion. 4 to 8 feet.

9. Medium to coarse crystalline limestone, light gray in color. Distinct layers of light chert are numerous towards the bottom.

Some of this chert is translucent. Minor joints at various angles developed by weathering. Calcite veins are numerous and minute and form a network through the member, which weathers red and brown. 24 feet.

10. Similar to No. 9 but darker, thinner bedded, and more coarsely crystalline. Wave marks are pronounced about two feet and a half from the top. 9 feet.

Note: Small faults of 10 inches and 2 feet respectively below and above No. 10. Numbers 9 and 10 constitute a rather mashed zone.

11. Dove colored and pink mottled limestone, much jointed into small cuboidal pieces. Fine grained, felsitic with no chert. Inconspicuous veins of hematite and limonite. 2 feet.

12. Gray blue, massive, dense, fine crystalline limestone, coarser towards the top. One heavy layer. Many heavy calcite veins some as thick as a half an inch, at right angles to the bedding planes. Traces of pink common in the lower parts. 6 feet.

13. One foot layer of coarsely crystalline limestone, greyish blue in color. 1 foot.

14. Blue gray, fine crystalline limestone, which is rather heavy bedded. There are three zones of chert nodules located respectively at the top, middle, and base. The chert is both light and dark. Calcite crystals occur in veins and in bunches. The bedding is not distinct but there are many irregular joints. Weathers a dirty brown. No fossils seen. 25 feet.

15. Bluish limestone in layers of two feet each, fine grained and dense at the bottom, with coarse crystalline layer, ill defined and of uneven thickness at the top. Calcite veins minute. Darker than most of the units; has siliceous black shale layers in which are embedded fragments of a very different limestone. These shales vary in thickness from a knife edge to five or six inches and are crumpled in many places. Wave marks at the top. No chert. Former small cavities in limestone are filled with calcite crystals. 11 feet.

16. Single layer of light bluish limestone with conchoidal fracture. No chert but much calcite veining, often more than a half inch in thickness. Mostly fine grained, but with pieces of coarse crystalline limestone and sandstone embedded in the layer. 6½ feet.

17. Dark gray crystalline limestone, rather massive but with bedding concealed. Many crooked joints running in all directions developed by weathering. The lower six feet are coarser crystalline than the rest, with threads and knots of chert throughout, calcite veins and bunches of crystals all through the member but increasing towards the top, where a mottled appearance is developed. Some small shale lenses. Pyrite is present in cubes and pyritohedrons, and there are pseudomorphs of limonite and hematite after these crystals. Weathers dark to black with chert and calcite in relief. 20 feet.

18. Color the same as in 17, but lower part has red streaks and spots. A dense, finely crystalline, felsitic appearing limestone in beds up to three feet in thickness. Several layers of light colored chert lenses and nodules occur. Calcite veins in places, with jointing rare and irregular. Weathers a rusty brown, not black. Bryozoans at the base. 11 feet.

19. Limestone, a dove color below to red above with calcite veins white to green and crystal lined cavities. Bedding is not distinct. Upper part becomes crystalline and slightly arenaceous. Veins are often not completely filled. Joints are irregular. No chert. Weathers brown. 4½ feet.

20. Thin red shale, thicker limestone, thicker red shale, and six feet of sandy and shaly, red limestone constitute this unit. It is capped by a few inches of shaly sandstone, which has reddish and greenish streaks. No layers are constant, the shale is fissile and ferruginous with inclusions of limestones. There is a layer of chert nodules in the upper limestone. 9 feet.

21. Dark blue, compact, fine grained, even layered limestone, mottled with light blotches of chert and calcite crystals. Joints are very rare but the formation breaks into even blocks to make good building stone. Weathers lighter but into a dirty brown. 3 feet.

22. Dark, red and green streaked, cross bedded sandstone, in two or three layers. White quartz in knots and crystals. There are also crystals of calcite and pyrite and chert nodules. 1 foot.

23. Dark blue limestone layers of three inches to three feet, which is darker above. Weathers a dirty gray to buff. The upper part has cavities lined with calcite and the entire unit has quartz

lined cavities. There are red blotches on the surface due to oxidized iron. 10 feet.

24. Interbedded black and white chert and shale layers, with one irregular limestone layer about four inches in thickness. The bedding is more distinct towards the bottom where jointing becomes abundant. There are several waved surfaces. Calcite veins and nodules with large pseudomorphs of limonite.

5 feet.

25. Several grayish, dense, limestone layers of less than two feet each in thickness. The upper layers, on weathering, bring out the thin bedding. There are also thin partings of light, calcareous shale. Joints are rare and irregular. Red blotches and threads, with little calcite and no chert. Fossils seen about half way up the unit. Limonite pseudomorphs. 11 feet.

26. Blue, heavy bedded, medium crystalline limestone with definite layers and chert nodules. Some layers are siliceous but not sandy; the main beds, six in number, show minor beds on weathering. There are several small shale partings and one ferruginous, flinty parting which is cross-bedded. There is also a one foot calcareous, shale layer seven feet from the top.

47 feet.

27. A faulted zone with slickensides common. Most definite fault is the southern and has a dip of fault plane about  $67^{\circ}$  N  $89^{\circ}$  W. Strike is therefore N  $1^{\circ}$  E. Two or more major faults occur to the north of first one but the dip and strike and amount of displacement are not determinable. This is a brecciated zone of greatly smashed and distorted strata. Probably 103 feet.

28. (We are now on the wagon road, having been on the railroad up to this point). Heavy bedded, bluish grey, finely crystalline limestone with layers and nodules of white and light blue chert, some layers of which are 2 inches thick and single nodules 6 inches across. There is little jointing but there are calcite bunches. The top of the unit is wave marked with crests three feet apart, with a shaly parting at the surface. Weathers red and rusty. 27 feet.

Wave markings and shale partings may mark change in conditions and life, but there seems to be no change in dip or strike and little change in the lithological phase of the rocks. The wave marks and crests trend N 15 to 20 degrees E.

29. Grayish blue limestone layers above shale parting two inches to three feet in thickness. Joints are vertical but not at right angles to the bedding. Other joints give sharp angles. There are calcite veins and a little chert. There are several shale partings with cross bedding in the lower layers, but the third layer is leveled up. Lower layers have conchoidal fracture. Rock is fine grained to fine crystalline. Weathers to bring out the bedding. 34 feet.

30. Group of gray to brownish thin layers of quartzitic sandstone, with shale below. 2 to 4 inches.

21. Blue to blue gray, fine grained siliceous limestone, with much black and grey chert. One layer of the chert toward the top is nearly continuous. The unit has a hackly fracture with little jointing. Many calcite veins weather in relief. Weathers buff, brown and black. 3½ feet.

32. Felsitic to fine crystalline massive, bluish, limestone becoming lighter above. Bedding is not clear but is developed by weathering in the upper portion. In crystalline layers the calcite weathers out and feels like sand on the surface. Calcite veins weather in. Much black chert in layers of nodules. Jointing is rare. Top layer seems to be wave marked as well as others and there are some thin shale partings on the wave marked surfaces. Weathers a reddish brown to nearly black. 24 feet.

33. Several limestone layers similar to 32 but thinner bedded, capped by a thin bed of bluish to reddish shale a few inches in thickness. In some places the shale contains chert and limestone pebbles as if residual. 11 feet.

34. Series of broken limestone beds similar to 33 with three small faults of a foot or so. Solution work and a filled sink hole are present. The filling is chert, clay and sandstone pebbles. White chalcedonic chert in the lower part. There are two shale partings near the top about a foot apart. 29 feet.

35. Gray, rather massive, uneven bedded, finely crystalline limestone except three feet from the top where it is coarse. There is a pink layer two to four feet from the bottom. There are peculiar pits on the surface about six feet from the bottom. Weathers lighter than the stone to buff, not red. Calcite veins and nodules. Wave marks with a shaly surface at the base. 20 feet.

36. Blue, finely crystalline to felsitic limestone becoming lighter and more felsitic toward the top. Crystals of calcite throughout the entire section. The chert is not noticeable above the first ten feet. In this section, the rock is broken by the growth of concretions, giving a brecciated appearance and contorted beds. There are good dip joints, others are irregular and at various angles. Many of the layers are sandy. Pyrite, limonite, and siderite show on the surface. Weathers dark and differentially, emphasizing the chert in relief, and the calcite along bedding planes in depressions. Beds vary from one to two feet in thickness but there is one single bed of six feet.

53 feet.

37. Dark gray crystalline limestone which is nearly pure in beds which are for the most part four to twelve inches in thickness, but there is one bed of four feet near the bottom. There are bunches of calcite crystals in the thick layer and there are two chert layers, one at the top and the other three feet below. The upper one is of neat rounded concretions with concentric structure. Rock has conchoidal fracture. Weathers buff to brown with large curved surfaces.

12 feet.

Nos. 37 and 38 are found both on wagon and R. R. cuts.

38. Light and dark gray felsitic limestone which looks flinty. Conchoidal fracture. At the middle, there are two layers with pits and knobs which fit together like waffle irons. There is a little black shale along this bedding plane. Chert layers at the base. Weathers dirty buff to brown.

12 feet.

No. 38-44 are all found on Virginian railroad cut.

39. Dark blue, medium bedded crystalline limestone with some calcite veins. There are several shale partings near the top. Red threads occur in the blue limestone. Dip joints are the most pronounced but there are some others present. Near the base there is one arenaceous blue layer. Weathers a dirty brown with the veins weathering in.

25 feet.

40. Lower mottled layer with light and dark gray in bars and blotches. Fine grained and crystalline with calcite bunches showing clearly. The layers are six to twenty-six inches in thickness, with three small shale partings. No conchoidal fracture. Weathers a darker reddish brown.

10 feet.

41. Lower light steel gray layer of fine grained crystalline limestone. Fracture slightly conchoidal. Beds are from 6 to 15

inches. Joints are rare. There are calcite nodules but no veins and no chert. Fossils in a layer of thin black shale one foot below the top of the horizon. Weathers lighter than the rock to yellow. 7 feet.

42. Upper, mottled layer with light and dark grey in lines, bars and blotches. Crystalline and coarse grained more pronounced grains than in the lower mottled layer. There are a few calcite crystals and veins. No chert. Some oblique and irregular joints. One layer only. 2½ feet.

43. Upper, light steel gray layer of limestone. Fine crystalline with conchoidal fracture. The bedding planes are rarely smooth, some being fluted or pitted like waffle irons. Calcite veining in the joints, and there are shale partings between some of the layers. Calcite crystals are common in the upper portion. Two feet from the base there are quartz crystals, iron oxide and an unidentified green mineral. Weathers light. Fossils were found in this member in 1923 consisting of brachiopods, cephalopods, a simple coral one inch in length and the pygidium of a small trilobite. 11 feet.

44. Bluish to dark steel gray, massive but medium bedded limestone whose layers are two inches to three feet thick. It is crystalline and looks like chert but is quite free from it. Joints are rare and the fracture is uneven to conchoidal. Calcite crystals occur in nodules and a few veins. Weathers lighter than the rock to yellow. 4 feet, 5 inches to 10 feet, 8 inches.

Total thickness ..... 609 feet.

This division does not complete the Shenandoah, but it is as final as can be made in this area. Unit 44 is just below the Chickamauga but unit 1 is an undeterminable distance above the top of the Russell.

## THE ORDOVICIAN SYSTEM

### Introduction

Ordovician rocks are widely distributed in Giles County, forming parts of the valley floor and sometimes capping lower ridges. The series grades from limestone at the base to sandstone at the top, and shows a distinct graded transition; limestone to argillaceous lime to shale then to arenaceous shale, which grades further into shaly sand and at last becomes a distinct sandstone in the Bays.

The Chickamauga formation has the greatest economic value of any formation in this system. It has enormous possibilities as a cement horizon, can be used for road material or as a building stone. In addition to these values, it distintegrates into a very rich soil. The other formations of the Ordovician have little economic importance.

### **The Chickamauga Formation**

This formation takes its name from Chickamauga Creek in Walker and Catoosa counties, Georgia, where it outcrops extensively. The lower layers are usually composed of a chert breccia which separates it from the Shenandoah, but where the breccia is wanting the separation can be made where the light impure limestone of the Shenandoah is replaced by the blue fossiliferous beds of the Chickamauga.

The breccia mentioned above is in some places 50 feet in thickness and varies from coarse at the base to fine at the top. The breccia consists of chert and non-crystalline limestone fragments in a crystalline limestone matrix. The chert fragments are sometimes as large as 15 inches in their greatest dimension and are always angular and lie in all positions in the matrix. In some localities fragments of sandstone, vein quartz, and quartzite occur along with the chert. This breccia seems to occur in the same horizon as the Birmingham Breccia of Georgia and Alabama, and like that stratum records uplift and erosion somewhere not far distant.

The Chickamauga is usually a blue, flaggy limestone, heavier bedded towards the base. It is sometimes separated from the lower formation with difficulty; however, the base generally carries large quantities of black chert which can be used as a distinguishing feature since the upper Shenandoah contains only light chert. The formation has a hackly fracture and usually weathers blue with water worn rounded forms characteristic. This limestone is more jointed and thinner bedded than the average Shenandoah. The calcite veining is also more prominent in this formation than in the preceding one. The thickness varies from 800 feet on East River Mountain to 700 feet on Big Walker Mountain. At the Virginian Railroad cut at the Narrows 806 feet of Chickamauga is exposed.

The Chickamauga is the great marble producing formation of

the South, but in this locality, while there are a few small occurrences, it is a coarse grained, dull gray rock fit only for building purposes. Like the Shenandoah, this limestone disintegrates into a rich soil, characteristic of such fertile spots as Burke's Garden and the Pearisburg areas. Unlike the underlying formation, however, the undesirable residual mantle of chert is not pronounced. This formation has its greatest development near the margin of the Appalachian Valley.

### Paleontology and Correlation

The following is a list\* of fossils found in the Chickamauga formation of Giles County:

<i>Tetradium fibratum</i>	<i>Ophileta complanata</i>
<i>Constellaria</i> sp.	<i>Stylarea parva</i>
<i>Dalmanella fertilis</i> .	<i>Echinosphaerites surantium</i>
<i>Heterorthis clytie</i> .	<i>Isotelus gigas</i>
<i>Dinorthis pectinella</i>	<i>Iliaenus americana?</i>
<i>Hebertella clytie?</i>	<i>Rafinesquina</i> sp.
<i>Girvanella</i> sp.	<i>Strophomena</i> sp.
<i>Solenopora</i> sp.	<i>Leptaena rhomboidalis</i>
<i>Eospongia</i> sp.	<i>Orthoceras</i> sp.
<i>Agnostus</i> sp.	<i>Batostoma</i> sp.
<i>Malcurea magna</i>	<i>Plectambonites pisum</i>
<i>Hormotoma artimesia</i>	

This list seems to indicate that the Chickamauga is early Ordovician in age, as there are forms here which are characteristic of the Beekmantown, Chazy and early Trenton of New York. Almost the same fauna has been described by Ruedemann<sup>9</sup> from a conglomerate inclosed in the Normanskill shales at Ryse-dorph Hill, Rensselaer County, New York. The conglomerate is made up of pebbles of Beekmantown, Chazy, and early Trenton age. Beekmantown fossils, however, are also found in the upper Shenandoah, but here are also found Cryptozoöns characteristic of the Ozarkian system.

Portions of the above listed fauna are also found in the Stones River, Chambersburg, Murat, Athens, and Holston formations. In the Chickamauga, there is also found resemblance, faunally,

\* For the most part, after Bassler and others.

<sup>9</sup> Ruedemann, R., "Trenton Conglomerate of Ryse-dorph Hill and its Fauna." Bull. 49, New York State Museum, 1908, pp. 1-115.

to the Birdseye (Lowville) limestone of New York and its equivalent, the Tyrone formation of Kentucky. The Hermitage and Bigby formations of Tennessee are also closely related to the upper Chickamauga of Giles County.

### **The Chickamauga Formation Subdivided**

Section along the Narrows of the New River in the Virginian Railroad cut.

1. A coarse chert breccia, with fragments of non-crystalline limestone in a crystalline matrix. The chert fragments are two to fifteen inches in their longest dimension, are angular, and lie in all positions in reference to the bedding plane, often being in contact and sometimes in apparent layers. No calcite veins.  
3 to 10 feet.

The chert in the breccia mentioned above is identical with the fragments which weather out of the Shenandoah today.

2. Two layers of fine chert breccia, the fragments being two inches or less in their greatest dimension. Fragments are rarely in contact, nor are they in distinct beds, but are scattered throughout the somewhat crystalline matrix. A normal fault of 2 feet cuts across these two horizons.  
6 feet.

3. A finer grained chert breccia, the fragments being from one inch in their greatest dimension down to the most minute, but it is clearly a breccia, for the fragments occur in great numbers and lie in all positions. Quantities of these are collected at various intervals into beds, the fragments becoming smaller and fewer upwards, but they end abruptly near the top. The matrix is a fine grained, gray limestone in layers of four inches to four feet. No calcite veins, looks like the Shenandoah.  
45 feet.

4. A partly covered interval. Fine grained, light colored, medium bedded limestone with some shale partings. The calcite-veined chert extends to the base. The limestone beds are dove colored to dark blue and often have dark chert nodules, which sometimes are arranged in beds. There is some calcite veining in the chert. Toward the top of the section dark blue chert predominates with light colors more characteristic of the lower layers. There are open joints and bedding planes, and the usual weathered or water-rounded forms so characteristic of this formation.  
243 feet.

Brachiopods were found about 50 feet above the breccia, hence low in this member, on the west side of New River.

5. Dark blue to black, fine grained, dense, non-crystalline limestone with the bedding concealed, and not developed by weathering. There is considerable black chert in nodules and in layers of nodules. These nodules, as well as the limestone itself, are veined with calcite. The chert is brittle and ferruginous, and both the chert and the limestone weather a rusty brown. Calcite is light and conspicuous. Jointing is meager. Pyrite crystals occur. 20 feet.

6. A very dark, blue black limestone with a hackly, rough fracture. Many calcite veins and some bundles of calcite crystals. The veins run in all directions, but the larger ones are at right angles to the bedding plane. Bedding is irregular. Pyrite crystals are common. 7 feet.

7. Fine, even grained, light gray to bluish limestone with close bedding. Fracture is smooth, fluted, and curved. This division looks and sounds flinty. Only a few calcite crystals and veins. No chert. Two layers; the upper being the lighter. Considerable pyrite, crystalline lenses in the middle portion. Weathers a light brown. 4½ feet.

8. Massive, light gray layer of fine grained, flinty limestone, with many small calcite veins, as well as some pyrite in scattered crystals and veins. Conchoidal fracture. Beds thicken and thin out locally. Weathers a little rusty but lighter than the rock. Boundary between 8 and 9 rather indefinite. 5 feet.

9. Massive, coarsely crystalline, dark blue limestone with cuboidal fracture. Bunches and veins of calcite occur, mostly in the joints. This division has the appearance of granite at a short distance. No chert or fossils. At one time this bed was used extensively for lime. Weathers a rusty grey. 16 feet.

10. Dark blue to black, thin bedded limestone, with many chert layers in black brittle nodules. Fine grained, calcite veined, fossiliferous matrix with the chert nodules, which weather out. Pyrite crystals, also brachiopods, cephalopods, crinoid stems, and corals. 15 feet.

11. Partly covered interval. A dense crystalline, dark limestone. Some chert and many calcite veins. Weathers almost white. Fossils as in 10, with the addition of gastropods. 83 feet.

12. Heavy bedded, blue limestone, one to seven feet in the thickness of the layers, cherty and calcite veined as well as containing large crystals of calcite. Master joints. Weathers rusty and deep, showing the weathering to a depth of forty feet. Fossiliferous. Bryozoans are the most abundant, but horn corals, crinoids, cephalopods, and brachiopods in several species occur.

89 feet.

13. Coarsely crystalline, mostly thin bedded, steel gray to blue limestone, with several thin shale partings. Very fossiliferous—especially towards the bottom, much as in No. 12. Thicker bedded toward the top, with calcite veins becoming abundant; no chert.

16 feet.

14. Shaly, steel gray limestone and calcareous shales, thin bedded. Very fossiliferous but fossils very much broken up.

2 feet.

15. One solid layer of dark blue, crystalline limestone, strongly calcite veined and carrying many broken and mashed fossils.

2 feet.

16. Thin bedded limestone, more or less argillaceous, with shale layers. The limestone is crystalline and very fossiliferous, especially near the base. Beds are for the most part under four inches in thickness. There is very little chert or calcite, and only a few joints.

20 feet.

17. Heavy bedded, dark steel gray limestone. Coarse and fine grained in different layers. Very much mottled with small clay lenses and streaks. Calcite veins occur complexly branching as well as chert nodules which are often cut by these veins. There are two joint systems at right angles to the bedding plane. Weathers with less rounding than the ordinary Chickamauga. Tetradium remains rather abundant. Beds 3-8 feet thick. Would quarry well.

50 feet.

18. Thin bedded, fine grained, cherty limestone, gray to black in color. There are many thin clay partings and beds or layers of chert nodules are characteristic. There are a few calcite veins. Weathers light. Fossils are rare.

20 feet.

19. A partly covered interval. Light to dark grayish blue limestone which is medium to thin bedded. Calcite veins and black chert nodules in layers. Bryozoans found.

105 feet.

20. Argillaceous limestone, showing thin beds grouped into layers of two to eight inches. The layers are alternately clay and

limestone. The color is grey blue. There are many white calcite veins and some pyrite crystals. No fossils or chert. Weathers light. 15 feet.

21. Thin bedded gray limestone, with thin shales, rarely veined with the exception of the bottom layer. Much mottled with small amorphous masses in a coarser crystalline matrix. Seems to be slightly conglomeratic. There are many fossil fragments; bryozoans, trilobites, crinoid fragments, brachiopods, corals, etc. 7 feet.

22. Coarse crystalline, light gray limestone, strongly veined with white calcite and some pyrite. There is no chert, but there are many fragments of fossils and some very whole and distinct, girvanella, brachiopods, bryozoans, trilobites and pelecypods. There is one mottled conglomeratic layer as in 21. The joints are irregular and are, for the most part, filled with calcite. The weathering emphasizes the amorphous inclusions. 4½ feet.

23. Dark blue to gray, fine grained, non-crystalline limestone, shot with numerous calcite veins. Bedding emphasized by weathering. Dip joints. Has clay conglomerate or breccia. Ends with layers about three feet above the first rocks which have the Moccasin appearance. 22 feet.

The samples collected from the various horizons of the Chickamauga limestone in this section show a remarkable uniformity in composition. The high lime content of these strata is indicative of their present exploitation in other parts of the state and of their future development here.

Analysis of Chickamauga Limestone,  
Narrows section, Virginia<sup>10</sup>  
(J. H. Gibboney, Analyst)

	1	2	3
Insoluble .....	5.60	1.50	2.30
Alumina .....	0.78	0.56	0.60
Iron oxide .....			
Lime .....	51.40	54.76	54.06
Calcium carbonate .....	91.80	97.78	96.54
Magnesia .....	0.72	0.15	0.30
Magnesium carbonate .....	1.52	0.31	0.64

<sup>10</sup> Bassler, R. S., "Cement Resources of Virginia." pp. 189.

### The Moccasin Limestone

The Moccasin Limestone, correlated with the Athens Shale and the Tellico Sandstone of Eastern Tennessee, marks the transition from the hard blue limestone of the Chickamauga to the Sevier calcareous shales. The formation is composed of red and greenish blue earthy limestones having a mottled appearance, and always weathering with a characteristic hackly appearance. These limestones usually outcrop on the steep slopes of the valley ridges and thus give a pronounced color to the landscape. The formation occupies a position stratigraphically intermediate between the great limestones beneath and the shales and sandstones above. The exposed surfaces are often ripple marked or mud cracked, indicating that the seas were much shallower than before and at their minimum depth for a limestone to be formed.

These limestones take their name from Moccasin Creek, Scott County, Virginia. In thickness, they vary from 300 to 500 feet, being 344 feet thick at the Narrows. There are several layers which are of proper texture and composition to have value as lithographic limestones but are too thin and fragmented. They have been tried as such by the U. S. G. S. Towards the top of the formation, there are alternate limestone and shale beds in which the limestone is gray blue, resistant with a hackly fracture and splintering into fragments because the jointing is not at right angles to the bedding plane. The shale horizons are very weak, the red and yellow beds weathering rapidly into very sticky clays. The entire formation exhibits the splintery fracture described above. Calcite veining occurs, but is not a dominant feature.

### Paleontology and Correlation

For some time, the Moccasin limestone has been regarded as a transition formation between the great development of Ordovician limestones in the Powell valley and the equally great development of shale and sandstone in the eastern portion of the Appalachian Valley. If this were the case, and continuous exposures could be had, the formation should grade into lime on the west and shale in the east. Recent investigations show that this is not the case and that the Moccasin is but a single Ordovi-

cian formation.<sup>11</sup> Certainly, there is no appreciable gradation in Giles County.

Fossils are rare, but specimens of *Dalmanella testudinaria* and *Plectambonites sericeus* were found as well as fragments of *Triarthrus becki*. What faunal evidence there is, as well as the stratigraphic position of this formation, indicates a Mid-Ordovician age, equivalent in part, at least, to the lower Utica division of the New York classification.

### The Moccasin Limestone Subdivided

Section taken at the Narrows of the New River, Giles County, Virginia. First two members are on Virginian Railroad.

1. Bluish limestone, thin bedded and not obliquely jointed as in the rest of the formation. The last two feet of this division are separated from the rest by three or four layers which resemble the Chickamauga. Even bedded and calcite veined. Mud breccia in this member. 10 feet.

2. Red to light brown, fine grained, even bedded limestone. Jointing is oblique with splintery fragments which are emphasized by weathering. A few layers are bluish gray instead of reddish. Beds are from one to fifteen inches in thickness. One layer of hard, drab to grey lithographic limestone four inches thick about twelve feet from the bottom. Mud cracks are unusually prominent. 90 feet.

3. Lithographic horizon. Starts up the ravine leading from railroad to wagon road.

a. Hard, dense, blue, limestone layer with small calcite veins. 6 inches.

b. Continuation of normal Moccasin. 10 feet.

c. Second fine grained, hard, lithographic layer, cherty appearance. 1 inch.

d. Continuation of normal Moccasin. 1 ft. 8 inches.

e. Third lithographic layer. 2 inches.

The non-lithographic layers seem to be partly lithographic, but of an inferior quality. Total, 12 feet, 5 inches.

4. Gray, greenish to drab, hard limestone in beds three to twelve inches in thickness, weathering lighter and having the same oblique jointing and splintery fragments as noted elsewhere. 16 feet.

<sup>11</sup> Bassler, R. S., 'Cement Resources of Virginia.' pp. 167.

5. A covered interval on wagon road with soft shaly limestone and calcareous shale in the float. 117 feet.

6. Limestone and shales alternating. Six limestone horizons of gray to blue resistant beds. No chert nor calcite and rarely fossiliferous. Argillaceous and breaking into splintery pieces because the jointing is both at right angles and oblique to the bedding. Six shale layers of soft, crumbly, yellow and red material, weathering into a reddish yellow, sticky mud, which covers up the slopes.

Shales .....	17 feet (bottom)
Limestone .....	10 "
Shales .....	18 "
Limestones .....	1 "
Shales .....	3 "
Limestones .....	3 "
Shales .....	10 "
Limestones .....	4 "
Shales .....	6 "
Limestones .....	5 "
Shales .....	3 "
Limestones .....	8 " (Top)
<hr/>	
Total.....	88 "

Analysis of Moccasin Limestone from  
the Pearisburg section<sup>12</sup>  
(J. H. Gibboney, Analyst)

	1	2
Insoluble .....	11.73	7.66
Alumina .....	1.48	0.82
Iron oxide .....		
Lime .....	47.78	50.38
Calcium carbonate .....	85.32	89.96
Magnesia .....	0.24	0.35
Magnesium carbonate .....	0.58	0.76
Total .....	99.11	99.20

1. Impure, drab limestone.  
2. Red, clayey limestone.

<sup>12</sup> Bassler, R. S., "Cement Resources of Virginia." p. 194.

### The Sevier Shales

This formation, showing the transition from limestones to sandstones above, forms the steep slopes of the larger valley ridges. It takes its name from Sevier County, Tennessee and corresponds with the late middle and upper Ordovician of New York, that is, the late Utica and Eden shales. It is also probably equivalent to the Maquoketa shales in Iowa as well as part of the lead and zinc bearing formations known as the Galena limestones.

This formation, which varies from calcareous shales at the base to sandy shales at the top, is from 1250 to 1500 feet in thickness, the section at the Narrows measuring 1341 feet.

These shales are fossiliferous throughout, corals, graptolites, sponges, bryozoans, and cephalopods being found rather commonly. In the upper layers trilobite fragments are found and pelecypods are common. Brachiopods are found throughout. *Plectambonites sericeus* is especially numerous and seems to be characteristic of certain beds in the formation.

The shales are interbedded with thin limestone layers in many places, and on the whole the formation is weak and non-resistant as well as being thin bedded throughout. Like the Russell formation, these shales are also folded and contorted. The bedding is clearly defined but the jointing is not conspicuous except where it forms cuneiform pits. Blue, brown, green and gray color combinations are the most common ones, with calcite veining rather marked in some places.

This formation passes up into the overlying sandstones rather abruptly and thus the dividing line is not so difficult to establish at the top as at the bottom, where Moccasin conditions seem to reappear several times after many feet of Sevier shales.

### Paleontology and Correlation

In Sevier County, Tennessee, the formation overlying the Tellico, has been named the Sevier. This formation is not very fossiliferous ordinarily, but has a fairly well developed fauna in Giles County. Fragments of *Triarthrus becki*, *Plectambonites sericeus*, *Rafinesquina alternata*, *R. squamulata*, *Calymene* sp. and *Zygospira* sp. are most commonly found but both *Didymograptus* and *Monograptus* types of graptolites are also present.

From the faunal evidence, the shales are late middle or upper

Ordovician. The fauna, (what little can be found) of the Moccasin is also present in the Sevier so that there is no great difference in the age of these two formations. Late Utica, Eden and possibly early Lorraine, seem to be the times in the New York Ordovician scale, which are comprised in the Sevier of Giles County.

The Sevier Subdivided at the Narrows Section.  
Wagon road above Virginian Railroad

1. A hard, blue, even-bedded non-fossiliferous limestone, exhibiting the characteristic Sevier cleavage. One layer.  
1½ feet.
2. Gray, crumbly shale, weathering to clay. 2 feet.
3. Even-bedded limestones and shales. The former in four to eight inch layers, blue to dark blue, hard, and all but non-fossiliferous. The shales are in two layers, one being green and the other yellow, besides many shale partings. The jointing gives cuneiform pits in the limestone. Fossils begin in this horizon.  
18 feet.
4. Calcareous shales and thin limestones like the upper part of this formation, but more of a greenish gray color, and more crumbly. Soft with few fossils. This is the end of the transition from the Moccasin. A partly covered area. 20 feet.
5. Blue limestone in beds of one to eight inches. Fossils uncommon. A little shale and some calcite veins. 8 feet.
6. Shale with a slaty cleavage, dark blue, green and black in color. Fissile, much jointed and thin bedded. The shale is rather calcareous. Fossils are rare. 19 feet.
7. Thin limestones with a few interbedded thin shales. The limestones one inch to one foot in thickness, being dark gray to blue but weathering lighter and leaving much residual clay. Calcite veins are numerous and branching and some are as much as an inch and a half in thickness. This division is fossiliferous with the shells being much broken. The veins and fossils both weather out. Much jointed and cracked. Shale partings occur and are from paper thickness up to six inches, but they are not arenaceous. The beds are bent, crumpled, and folded as well as being faulted locally. Very fossiliferous. The brachiopods *Dalmanella testudinaria* and possibly *subaequata* and *Plectambonites sericeus* being very common and characteristic. 386 feet.

8. Thin limestones, one to twelve inches in thickness, interbedded with thin blue shales. More than half is limestone, hard, dense, blue, fossiliferous and calcite veined. Talus consists of limestone almost entirely. The limestone layers thicken and thin and are sometimes bent so as to reverse the dip. Several small concretionary layers are present. The upper feet are more limey and thicker bedded. In the central portion *Monticulipora* sp. are common and toward the top there are several species of coral. In the lower portion many graptolites of the *Didymograptus* and *Monograptus* types, *Asaphus gigas*, *Rafinesquina alternistriata*, *Chaetetes* sp., *Lophospira* sp., *Bellerophon* sp., and *Orthoceras* sp. are found.

224 feet.

9. A series with more shale than limestone, in little beds, none of which are more than one inch in thickness. Only about forty feet of this horizon is exposed. Fossils found are *Calymene* sp., *Raphistoma peracutum* and a *Monticulipora* species.

175 feet.

10. Alternating shales and thin limestones much like layer number 12. There are no distinct layers and the divisions are marked by numerous small faults of less than 15 inches.

123 feet.

11. Contorted limestone beds with interbedded calcareous shales and limestones. There are six layers, two near the bottom are two feet thick, then there are three layers, two to three feet thick, and a single three foot layer at the top. The fourth layer from the bottom has a conglomeratic phase near its top which was seen in both the railroad and wagon road cuts. Fossiliferous. Calcite veined. The limestone is blue while the shales are brown and greenish grey.

85 feet.

12. Calcareous shales, thin bedded, blue, greenish and brown, with many thin blue limestone layers full of fossils. The limestone weathers rapidly by solution leaving clay where the limestone layers were. Thus the limestones are usually indented in a weathered cut. Calcite veins are very abundant. 80 feet.

13. A limestone layer, grey to olive green and jointed so as to give "V" shaped notches and the cuneiform pits, 1-6 inches wide and 1-20 inches long. Surface weathers smooth but sharp angled corners project.

2 feet.

14. Calcareous shales containing a few layers of hard blue limestone. The limestone is very fossiliferous and in beds

6-12 inches thick, and contains calcite veins. The shales are gray, green and indifferent tints, and also fossiliferous. There are many thin sandstones 1-3 ft. thick jointing into regular angular and cubical blocks. The shales weather rusty and the limestone weathers by solution leaving fossil cavities and red clay.

113 feet.

15. Thin bedded, greenish, gray blue, calcareous shales with thinner, stronger layers mainly of flinty sandstone but none of limestone. There are many fossiliferous horizons some of which weather out porous. Brachiopods, pelecypods and bryozoans occur.

44 feet.

16. Thin bedded, bluish green, calcareous, and sandy shales with thin 2-4 in. sandstone layers every foot or two. These latter weather out in angular pieces like chert layers. There are many fossil zones and scattered fossils throughout the whole horizon.

18 feet.

17. Thick bedded, massive, dark olive green, calcareous sandstone in some places weathering shaly and in others like sandstone. There are many horizons of broken and well-preserved fossils. Brachiopods occur 6 ft. from the top. The rock is richer in fossils than the Bays.

19 feet.

The following analyses of the Sevier Shales will serve to indicate their approximate composition at the Narrows although the samples listed below were taken near Goodwins Ferry which is more than 20 miles up the New River.

Analyses of the Sevier Shale<sup>13</sup>  
(J. H. Gibboney, Analyst)

	1	2	3
Insoluble .....	5.12	41.48	71.88
Alumina .....	2.92	6.04	8.56
Iron oxide .....			
Lime .....	51.16	28.00	8.54
Calcium carbonate .....	91.39	40.00	15.25
Magnesia .....	0.25	0.30	1.27
Magnesium carbonate .....	0.53	0.64	2.68

1. Thin bedded, blue limestone, lower part of the Sevier.
2. Calcareous shale from the lower horizons of the formation.
3. Sandy shale from the Eden horizon of the Sevier Shale.

<sup>13</sup> Bassler, R. S., "Cement Resources of Virginia," p. 200.

### The Bays Sandstone

The sandstones and shales overlying the preceding formation are for the most part, red, yellowish red, or purplish red, but there are some green blotches which resemble, but are not, surface features. The thin bedded sandstones at the top pass downward into sandy shales, keeping the prevalent color and merging at last into the Sevier below. The formation takes its name from Bays Mountain in Tennessee.

This sandstone scratches very easily and weathers shelly. Some layers show cuneiform jointing developed to an unusual degree, and the jointing is good throughout, there being master joints in several localities. In some places, the sandstone is slightly quartzitic but for the most part the formation has been but very little metamorphosed. The fracture is usually uneven to conchoidal.

The conditions were not especially good for life development during the time these rocks were laid down, nor is the formation a good one for preserving fossil forms had life been present, hence fossils are found mostly in the lower, more shaly layers. There are several very distinctive nodular layers and cross bedding is quite noticeable as well as ripple marks, all indicating shallow seas. In the top layers, there are fine flakes of primary mica as well as some secondary chlorite along joint and bedding planes. The total thickness of the formation at the Narrows is 321 feet.

Usually the crest of the ridges is formed of Clinch, with the red Bays outcropping below, but in some places, especially in low gaps, the Clinch has been eroded away and the summit is then formed of the Bays Sandstone.

### Paleontology and Correlation

Fossils in some of the lower layers are well preserved and fairly numerous. *Hebertella sinuata* and *Orthorhynchula linneyi* are found throughout, as well as a large, unidentified ramose bryozoan.

It would seem from the faunal evidence as though the Bays was either Lorraine or Richmond in age. Lorraine forms seem to predominate. If this correlation is correct, the Bays sandstone of Giles County is younger than the typical Bays of Tennessee,

which is beyond question Middle Ordovician (Black River).<sup>14</sup> In this case, the name Bays is a misnomer, as applied to these red sandstones of Giles County. In northwestern Virginia, the name Juniata has been applied to a similarly situated red sandstone, whose age is beyond doubt lower Richmond. It would seem, then, that the name Juniata might be used here rather than Bays.

The Bays Sandstone Subdivided  
Narrows Section. (Wagon road)

1. Medium bedded sandstone with thinner shales, green blotches becoming bands in places. Even bedded, several layers carrying broken fossils, red with iron. Base of formation marks the change in color from dark red to green. 20 feet.

2. Thin bedded, purplish shaly sandstone, carrying several beds of broken shells. Trilobite fragments are common. A ferruginous layer. 9½ feet.

3. Lower nodular layer flattened, concretionary-like masses one to two inches thick and six to ten inches broad. These are not concretions, and do not take the iron rust on the curved cleavage faces as do those of similar appearance in the upper nodular layer. The upper and lower parts are the richest in these masses and are the most shaly. The middle is more massive and sandy with conchoidal fracture and many green blotches. Fossils are in fragments in the upper portion. 5½ feet.

4. Cross bedded layers of dark red sandstone with thin interbedded shaly sandstone layers. All are cross bedded even to great wedge-shaped masses of many layers. Some ripple marks, and much chlorite in the joint planes as well as some on the bedding planes. Quartz is also found deposited in veins. Slickensides along some bedding planes. 32 feet.

5. Thin sandstone layers which are arenaceous, micaceous, and shaly. This division is dark red, thin bedded and crackled, and much shot with minute joints. When it is freshly exposed, it resembles a single massive layer, but with weathering it crumbles into fragments. Top layer is a thin green shale. 2 feet.

6. Upper nodular layer. Dark red sandstone, upper one and one-half feet massive, even grained and breaking with curved surfaces which scratch very easily. Middle two feet are nodular

<sup>14</sup> Stose, G. W. and Miser, H. D., "Manganese deposits of Western Virginia," pp. 29.

and look concretionary but are not. Curved pieces break out giving rounded masses, but each has the same composition as the rock above and below. Red, ferruginous quartzitic sandstone with quartz veins. Weathering of the iron has gone on along these curved planes and thus has aided the spheroidal breaking. The lower two feet are rarely nodular but otherwise they have the same appearance. 5½ feet.

7. Red sandstone and arenaceous shales, which when first exposed, seem to be thick, massive beds. When weathered, the thin shaly beds appear and the rock crumbles. Fine and even grained with little cross-bedding. Regular for long distances. Usually dark, brick red, rarely gray. Scattered green blotches occur as well as calcite veins. Fine flakes of mica are probably primary but the chlorite veins are secondary. 47 feet.

8. A covered interval, which from the float seems to be largely soft gray and green as well as red sandstones and shales. 197 feet.

Analyses of a Single Sample of the Bays Formation  
from near Glade Springs, Virginia.<sup>15</sup>  
(J. H. Gibboney, Analyst)

	Per cent
Insoluble .....	90.18
Alumina and Iron oxide .....	5.72
Lime .....	0.64
Calcium carbonate .....	1.14
Magnesium .....	0.03
Magnesium carbonate .....	0.07

## THE SILURIAN SYSTEM

### Introduction

The Silurian rocks of Giles County are dominantly sandstones, (sometimes semiquartzitic), but there are also interbedded shales, and a few conglomeratic layers. These rocks are divided into the Clinch and Rockwood formations, but in addition some rocks classed as the lower Giles may be in part Silurian.

Silurian strata outcrop in a continuous band, about a mile and a half wide, along the northern border of the county, but do not extend into the panhandle because they dip south and thus in

<sup>15</sup> Bassler, R. S., "Cement Resources of Virginia," p. 170.

the valley they are carried south. They are also present over a considerable area in the eastern as well as the western mountain areas, but their outcrop on the Walker Mountain range lies only in a narrow strip which is very restricted in Giles County.

The Clinch and the Rockwood are both mountain making rocks and they are usually found capping ridges. Iron ore of the Clinton type is found in the Rockwood but has not been exploited to any extent here. There are about 550 feet of Silurian strata in Giles County.

### **The Clinch Sandstone**

The Clinch Formation, taking its name from Clinch Mountain, is found throughout the entire Appalachian system. It corresponds to the Medina Sandstone of New York. All the important valley ridges owe their existence to this heavy plate of sandstone which has preserved summits at or nearly at the level of the oldest recorded peneplain, while adjacent areas have been eroded to the present valleys.

This formation is easily separable from all the others because of its massive character. It usually varies between 125 and 300 feet in thickness, there being 140 feet in the Narrows exposure.

This rock is a semi-quartzitic sandstone, coarse to fine grained, sometimes conglomeratic with large quartz pebbles. Slickensides are rather common because the beds are so stiff that they break and slide over each other rather than bend. The formation weathers light brown to yellowish bronze color, red and purplish red occurring in places. It has an uneven fracture, is fairly even bedded, and very dense and resistant. These rocks form the larger rapids at the Narrows of the New River.

The formation contains arenaceous shale layers which become more numerous towards the top. While fucoids are found in some places, the formation may be regarded as practically non-fossiliferous.

### **Paleontology and Correlation**

The Clinch thickens off to the north and east, so that while in Giles County its thickness is 140 feet, it is 300 feet thick in northern Virginia where it makes Cacapon Mountain. On Massanutten Mountain, sandstones of equivalent age are called Massanutten, while in Pennsylvania and Maryland, the same formation is known as the Tuscarora sandstone.

Fossils are rare, but some specimens of *Lingula cuneata* can be found in the shaly division. Excellent specimens of *Scolithus verticalis* and *Arthropycus harlani* have been found on Angels Rest and Peters slopes. What faunal evidence can be found then, as well as stratigraphic position and lithologic character, seem to indicate Medina age for the Clinch.

The Clinch probably rests unconformably upon the upper Ordovician Bays sandstone.

#### The Clinch Sandstone Formation Subdivided Narrows Section

1. Lower part of Clinch. Sandstone in layers from one inch to eight feet, with thin arenaceous shale partings, one-fourth to three inches in thickness. Colors are gray and greenish blue as well as a purplish gray and it is not until weathered that the formation assumes the bronze red tint due to the iron impurities. Quartz pebbles cemented with iron, silica and colored by the iron are metamorphosed into a fair quartzite. The pebbles attain a size commonly equal to that of a hickory nut, rarely 2-3 inches in diameter, and are of older quartzite and vein quartz. There are some minor faults in this division. 120 feet.

2. Upper layers. Five shale layers, nearly four feet thick, all arenaceous, in variegated colors of green, blue, red and brown as well as various tints, and being thinly laminated—separated by four layers of quartzitic gray sandstone of about six inches in thickness. These beds vary notably from place to place.

20 feet.

#### The Rockwood Formation

This formation takes its name from Rockwood, Tennessee, where it has been used as an iron ore for many years. It is a heterogeneous mass of shales and sandstones, corresponding to the Clinton formation with its iron ore of New York and Alabama. In the Narrows of the New River, 292 feet of this formation are exposed but in some localities its thickness runs as high as 400 feet.

In some places, the sandstone is semiquartzitic, and such a layer forms the upper rapids in the New River at the Narrows. The jointing is good and is for the most part cuboidal. The dominant color of the formation is red on account of the large iron content. These rocks are fossiliferous to some extent, fucoids,

bryozoans, brachiopods, pelecypods, trilobites and corals being recognizable but in many places the fossil remains are too fragmentary to be identified.

The Rockwood is extremely thin bedded in some localities but the average bedding is medium. Ocherous sands occur in places and several layers could be used for building purposes with excellent results. One quartzitic layer with a conglomeratic phase is very similar in every respect to the Clinch.

Many of the higher ridges are capped with Rockwood which is sometimes the source of the mountain iron ore. The ore, however, is in this locality either of such low iron content or is so inaccessible that it promises no definite economic value for years to come. In the case of the Rockwood ore, it seems as if the upper layers in being eroded away have left their iron content to be leached down into the lower layers and thus they are always the richest ones.

#### Paleontology and Correlation

Fossils are usually quite numerous in the Rockwood, but in Giles County only a few were identified. The age of these fossils is Clinton. In some places in the state, rocks of Cayuga age have also been called Rockwood, but in Giles County, this formation is entirely Clinton.

The white quartzitic layer near the top is thought by Stose and Miser<sup>10</sup> to be of the same age as the Keifer sandstone of Pennsylvania and Maryland.

#### The Rockwood Formation Subdivided Narrows Section—Wagon Road

1. Thin shales and argillaceous thin sandstones, in a variety of colors, such as blue, red, and green. Weathers to sandy mud. Much jointed and crumbly. Several red sandstone layers in the shales. At the base are found *Camarotoechia neglecta* in two zones about eight feet apart, very abundant but quite alone. About 75 feet above these fossil beds a rich fossil horizon occurs carrying *Anoplothea plicatula*, *A. hemispherica*, *A. plano-convexa*, *Chonetes cornutus*, *Diocalymene clintoni*, *Buthotrephis gracilis*, var. *crassa* and var. *intermedia*. About 114 feet above the base are found *Bumastus barriensis*, *Calymene blumen-*

<sup>10</sup> Stose, G. W. and Miser, H. D. "Manganese Deposits of Western Virginia." pp. 30.

*bachii*, *Liocalymene clintoni*, *Beyrichia lata*. This array of forms establishes the Clinton age for the Rockwood, and suggests that the lower Rockwood is the equivalent of the middle or upper Clinton of New York. 120 feet.

2. Dense, quartzitic sandstone in three or four layers, one of which is about 18 inches thick. The sandstone is coarse grained at the base. 3 feet.

3. Ferruginous shales and sandstones in alternate beds. The average color of the sandstones is red. The shales are thin, gray and green. 18 feet.

4. Dark red, ferruginous, quartzitic sandstone, irregularly bedded and jointed. Weathers to a rusty brownish red. Irregular blocks as large as five feet thick weather out. Hematite in certain places. 5 feet.

5. Alternating sandstones and shales. The sandstones are two to five inches thick and are red and grey, dense and quartzitic. Regular cuboidal jointing into brick like blocks. Thin shale beds of a smooth greenish gray color and not sandy. Bryozoans are common. Fucoids? 6 feet.

Section described now goes to Virginian cut.

6. Shales, having soapy feel, without grit. Gray, green and yellow, weathering soft, punky almost black. Thinly laminated. Brachiopods. 13 feet.

7. Layers of blue, gray, and pink, dense quartzitic sandstone, with a little shelly material in the upper half. Weathers a dark brown and red. *Atrypa reticularis*. 6 feet.

8. Coarse buff sandstone, not cemented and not quartzitic with ferruginous veins with crooked branching, which seem to be impregnation of the natural pore spaces between the grains of sand. Iron is more abundant and much darker red than usual in this division. There are many cavities an inch or less across. The rock is thin bedded but one layer in the middle part is 2 — 2½ feet thick. Possible bryozoans were found. 7 feet.

9. Gray sandstone, with fine gray blue shale layers. The sandstone is quartzitic in beds of two to eight inches. One group seems to be a heavy one but shows thin when weathered. Near the bottom several layers are a pronounced red and weather rusty. Strong cross bedding. No fossils. 15 feet.

10. Black, carbonaceous, shaly layers, as well as red, brown and gray ferruginous layers. It is always sandy with quartz

grains rounded and some of the cavities are quartz filled. A few red sandstone layers. The shale is fissile, thin bedded and weak. Fossils found but badly mashed. 7 feet.

11. Strong sandstone layers, one to six inches thick, gray, reddish and mottled. Weathers a dark red and rusty. Layers are even and continuous. Very thin, sandy shale partings. Pelecypods. 2 feet.

12. Soft, shaly sandstone in thin beds, weathering easily into clayey sands. Dark gray, yellowish and brown. Brachiopods. 2 feet.

13. Ripple maker. Resistant gray quartzitic sandstone with pink lines and gray mottling, heavy and cross bedded. Heavy pebbles in a fine grained matrix and resembles conglomeratic layers of the Clinch. Cavities of considerable size are more or less filled with chalcedony and quartz crystals. No fossils seen. 9½ feet.

14. Covered interval of soft shaly material. 38 feet.

Near the base were found *Tentaculites minutus*, and *Telluromya lata*.

15. Layers of purple and red, quartzitic sandstone. Fine bedding lines of alternate light and dark red often are apparent. Two to six inch layers grading off thinner and weaker toward the top. Weathers a rusty bronze. 7½ feet.

16. Three to six layers of dense, hard red to purple quartzitic sandstone, even bedded and fine grained. Some of the layers split up on weathering into two or three layers. Would make a handsome building stone as it weathers a beautiful bronze. There is one greenish layer. 3½ feet.

17. Between fifty and seventy layers of slightly argillaceous sandstone and quartzitic sandstone, becoming thinner and weaker towards the bottom. 2 feet.

18. Strong quartzitic sandstone beds two to eighteen inches in thickness and slightly crackled and broken. Gray, greenish and red in streaks. Weathers rusty, reddish and rough. Five feet from the top is a layer of loose material, caused by the weathering and leaching of a more porous layer. Ocherous sands in some places; in others apparently concretionary. It probably is not concretionary but is a residual structure brought out by weathering. Corals near the bottom. 15 feet.

19. Thin bedded sandstones with little shale partings; sandstones one-fourth to five inches thick. Buff to gray with no red. Weathers a uniform buff. Shattered and crackled but there are no master joints. Some layers are quartzitic but some are also loose sands. Some layers have the appearance of one in unweathered surfaces. Myriads of *Cytherellina* in the middle.

13 feet.

This does not complete the section, as a part of the Rockwood is faulted out. On the west side of the river the fault continues westward but is some distance farther south so as to leave all the Rockwood and a considerable section of Giles north of the fault. There may well be, then, 100 feet or more of Rockwood missing.

## THE DEVONIAN SYSTEM

### Introduction

The outcrops of Devonian strata are confined to restricted exposures having a general northeast southwest strike. One of these outcrops is on the northern flank of Brushy Mountain, another extends into Giles County from Bland on the west, and appears for some little distance to the east of the Stange mine on Flat Top Mountain. Still other outcrops are found in the upper courses of Clendenning, Little Stony, Stony, and Johns Creeks, as well as in a small strip across the Panhandle. In the south slopes of East River Mountain are considerable areas of Giles beds extending from New River almost to the Bland-Giles county line.

There are no good sections of lower Devonian exposed in Giles County so that there is some confusion as to the exact age of the Giles formation. Some of the rocks which appear above the Clinton, and are almost certainly Cayugan in age, are classed as Giles, yet the upper Giles bears a marked resemblance faunally, stratigraphically, and lithologically to the Oriskany. There are also occasionally limestones and cherts below this sandstone which have been referred to as Helderbergian.

The Oriskany formation is of importance since it is in this horizon that many of the manganese prospects of the county are located. The other divisions have no economic value. The entire Devonian as observed in this area is less than 3000 feet in thickness, but it occurs in such scattered outcrops, and in places is so faulted that this figure may be either too large or too small.

Limestones to limey shales, to black shales, grading at last to sandstones at the top, constitute the normal succession of Devonian strata in Giles County.

### The Giles Formation

Above the Rockwood is a group of strata of diverse characteristics, but hard to separate in the field. In the Kimberling Creek area, in the western portion of the county, there is at the base of the Giles some forty feet of blue limestone, calcareous shale at the base but heavy limestone at the top. This is followed by coarse, ferruginous sandstone, some fifteen feet in thickness, made up of small quartz pebbles. Above this, there is cherty limestone, about thirty-five feet thick, which is always present along the outcrop and is the key to the subjacent strata, and following this, there is an undetermined thickness (probably less than 100 feet) of yellow-green sandstones.<sup>17</sup>

### Paleontology and Correlation

Little time was spent on the fauna of the Devonian formation. The upper divisions of the Giles are Oriskany and Helderbergian in age, but the two lower divisions, as described above are without faunal record in Giles County. On the south slope of East River Mountain, between Narrows and the west county line, there are many exposures of the beds grouped as Giles. They are cut somewhat parallel to Wolf Creek by a fault so that their resistant layers repeat in places to form several rocky ridges. Farther west in Wolf Creek Valley and quite near the county line the Giles outcrops in two strips with Rockwood above the northern strip and again between the strips, while Shenandoah appears to the south. A fault has let the Giles down against the Rockwood, thus preserving it. Erosion has removed the Giles from a part of the Rockwood farther down the slope and a large fault near Wolf Creek has carried the Shenandoah up to the height of the Giles. In these areas considerable detailed work has been possible, and the following correlations have provisionally been made:

1. Blue calcareous beds varying from firm limestones toward the top to weak shales at the base, and resting immediately on the Rockwood. 40 feet  $\pm$

<sup>17</sup> Campbell, M. R., U. S. G. S. Folio No. 26.

2. Rather even bedded sandstone and coarse but even grained sands well cemented with iron oxide. Many molds of pelecypods in the main poorly preserved. 20 feet  $\pm$

3. Limestone and chert. Whole beds are of chert, others are a chert breccia with a meagre limestone matrix. In no place was number 4 present with number 3 eroded away. Fossils were found in the chert only. The colors are red, tan, pink, yellow and gray. The bedding is irregular to imperfect. 40 feet  $\pm$

4. Coarse yellow, buff, tan and green sandstones in part loosely cemented, in part almost quartzite (boulders travel long distances in the float). Many molds of *Spirifer mucronatus*, with hinge line much extended and a few *S. arenosus*. Some of the beds are shaley but the member is for the most part sandstone. 100 feet  $\pm$

These four members were found together in two or three places and one or more of them were recognized repeatedly but they never could be traced far. They became covered with their own waste or float from the Rockwood. Nevertheless the group as a single map unit was placed on the map almost all the way from the river west to the county line. The area varies greatly in width because in many places the greater part of the Giles has been eroded away from the Rockwood.

It seems reasonable to correlate No. 1 with Coeymans, No. 2 with New Scotland, No. 3 with Becraft and No. 4 with Oriskany, but any such allocation is only tentative. No. 4 and Oriskany are the most confidently connected. There is much less assurance concerning the other three.

There seems to be an unconformity at the base of the Oriskany, but the details of the occurrence or absence of different parts of the Cayuga and Helderberg are not well known in this area. It seems to the writers that future work here will justify a revision of the nomenclature of the lower Devonian which may result in at least three new division names for rocks which are at present simply called Giles.

### The Romney Shale

Overlying the Giles, there are in a few places in Giles County, dark shales to which the name Romney has been given. These shales grade insensibly from black carbonaceous shale, which is

replaced by green, sandy shale, to rocks which in turn merge into thin bedded green sandstones. Only the dark division is called Romney, the upper portions being designated as Kimberling.

The true Romney shale at the type locality, Romney, W. Virginia, is reported to contain fossils of Onondaga, Marcellus, and Hamilton age. The Romney of Giles County is thought by Stose and Miser to be of Genesee and lower Portage time and therefore younger.<sup>18</sup> At the base of the Romney, however, near Big Stone Gap there have been found fossils of Hamilton and Marcellus age in a thin layer of disturbed, rusty, black shale. True Romney has been deposited, it would seem, but has almost entirely been removed by erosion. The thickness of the so-called Romney is about 500 feet.

Again, exposures in Clendenning Creek are clearly of Marcellus age for they contain the following forms: *Camarotoechia* cf. *exemia*, *Stropholosis truncata*, *Leiorhynchus limitare*, *Styliolina fissurella*, *Tentaculites bellulus*, and *Ambocoelia umbonata*. These include forms said by Kindle<sup>18a</sup> to be characteristic of the Marcellus. To continue, none of the forms said by H. S. Williams to be characteristic of the Genesee have been found in the Narrows section. Hence, the evidence from both sides seems to point to Marcellus age for the Romney of Giles County.

### The Kimberling Shale

As has been mentioned before, this formation passes from greenish or gray fissile shale to sandstone and appears to be about 3000 feet in thickness. Fossils, which are not numerous in this formation, indicate Portage and Chemung age. The sandstone at the top may in part be Catskill although no flora or fauna were found in this horizon.

None of the Devonian of Giles County presented outcrops which could be subdivided easily since by far the greatest portion of these rocks is shale which weathers very rapidly.

<sup>18</sup> Stose, G. W. and Miser, H. D. Manganese Deposits of Western Virginia. pp. 38.

<sup>18a</sup> Kindle, E. M. Jour. Geol. Oct.-Nov. 1906. Faunas of Devonian Section near Altoona, Pa.

## THE MISSISSIPPIAN SYSTEM

**Introduction**

The Mississippian formations, which are the youngest consolidated sediments of Giles County, appear only in the panhandle district. The base of the series is sandstone, which is followed in turn by shales, limestones, more shales, and is, in this area, terminated by the Hinton formation. The total thickness in Giles County is less than 4500 feet, but it is very hard to measure on account of the covered areas.

**The Price Sandstone**

Overlying the upper Devonian sandstones, there is a granular, bluish white sandstone which contains scattered quartz pebbles. This sandstone is continuous with one in Bland County (of apparently the same age) which has been called Price by Campbell.<sup>19</sup> In other parts of Virginia, a sandstone very similar to the Price, and of basal Mississippian age has been given the name Pocono. The writers believe that the two are of the same age and are a stratigraphic unit.

No fossil plants or invertebrates were found in this division.

**The Pulaski Shale**

This is a bright red shale, which is usually brought in direct contact with the middle Price due to the faulting out of the upper portion of the latter formation. This, however, is not the case in the Narrows section, and yet only a poor exposure of what was thought to be Pulaski could be found, due again to the rapidity with which those shales weather to cover themselves.

**The Greenbrier Limestone**

This formation is made up of heavy blue limestones, which are sometimes cherty and always fossiliferous. At the top, however, it becomes rather shaly and passes into a calcareous shale at the base of the overlying formation. Several considerable sandstone horizons also occur in the Greenbrier.

**Paleontology and Correlation**

Some of the more common faunal forms of the Greenbrier of Giles County, as listed by Bassler and others, are given in the list which follows:

<sup>19</sup> Campbell, M. R. U. S. G. S. Folio No. 26.

<i>Spirifer increbescens</i>	<i>Zaphrentis spinulosa</i>
<i>Eumetria marcyi</i>	<i>Fenestella</i> sp.
<i>Seminula subquadrata</i>	<i>Archimedes</i> sp.
<i>Seminula trinuclea</i>	<i>Derbya crassa</i>
<i>Productus fasciculus</i>	<i>Allorisma maxvillensis</i>
<i>Productus cestriensis</i>	<i>Bellerophon sublaevis</i>
<i>Pentremites godoni</i>	<i>Spirifer keokuk</i>
<i>Pentremites pyriformis</i>	<i>Dielasma turgida</i>

Professor Prosser and Dr. R. B. Rome collected a very similar fauna from the Greenbrier of Maryland for the state survey. The Maxville limestone fauna of Ohio is also very similar and the Greenbrier has been regarded as the Appalachian equivalent of the Maxville by Morse<sup>20</sup> and others. This is no doubt in part true, but the Greenbrier seems to include more than the Maxville.

#### The Greenbrier as Divided by Bassler<sup>21</sup>

Probably the best and most detailed section of the Greenbrier limestone to be observed in Virginia may be seen along the Norfolk and Western Railroad near Lurich, in Giles County. Here all of the beds are fairly well exposed and the section may be considered as typical for the region. For this reason all of the variations in the strata at this point were noted. The section is, in ascending order, as follows:

##### Geologic Section, Greenbrier Limestone Vicinity of Lurich, Virginia

7. Thin-bedded blue limestone with beds of blue and yellow shale. 400 feet.
6. Compact blue to black argillaceous limestone in thin flaggy layers, much fractured. 170 feet.
5. Compact blue-black, fine-grained limestone alternating with coarsely crystalline fossiliferous strata, with blue limestone and yellow shales in upper part. 150 feet.
4. Drab and blue shales. 80 feet.
3. Massive blue and argillaceous limestone with a few shaly beds in the upper part. No chert observed. 90 feet.
2. Drab and yellow calcareous shales with occasional bands of compact blue limestone. 180 feet.

<sup>20</sup> Morse, W. C., "The Maxville Limestone," Bull. 13, Series No. 4, Ohio Geol. Survey, pp. 109-111.

<sup>21</sup> Bassler, R. S., "The Cement Resources of Virginia," pp. 275.

1. Dark blue to black, heavily bedded limestone with many small chert nodules. *Productus*, *Zaphrentis*, and *Fenestella* observed. 175 feet.

### The Bluefield Shale

This shale, which directly overlies the Greenbrier, varies from calcareous at the base to sandy at the top, where it is capped by a heavy bed of quartzite. It marks the transition period between the deposition of limestone below and sandstone above.

The formation takes its name from the town of Bluefield, West Virginia, where it is typically developed, and attains a thickness of 1250 feet. The section at the Narrows is also a little over 1000 feet in thickness. Some horizons are quite fossiliferous in the vicinity of Rich Creek.

### The Hinton Formation

This formation is composed of impure limestones, argillaceous shales, sandy shales and sandstones, but it is so heterogeneous that no bed may be mapped separately. It is especially well developed along the New River in the vicinity of Hinton, West Virginia, from which place it takes its name. In Giles County there are 1000 feet exposed, but the section is not complete. There are several fossiliferous zones in this formation. The calcareous beds are rich in flat coiled gastropods. *Stigmara* and *Calamites* are rather common in some of the divisions.

### Tertiary Gravels

Mention must here be made of the Tertiary gravels which are found even at considerable altitudes in the open valley between Butt and Angels Rest mountains. Some of these deposits occur at elevations as much as 350 feet above the present river bed. The exact status of these deposits is in doubt, but they may in part correspond to the Lafayette or Orange Sand formation of Oligocene time, which is found in many of the states just to the west of the Appalachians. This formation often has a thickness of twenty to thirty feet and is composed of sands, gravels, and even rounded boulders. It was derived from the insoluble residue of older formations such as chert and quartzite pebbles, together with limestone fragments side tracked by the streams before wholly ground up. The color is often yellow or orange, and the deposits are quite conspicuous occasionally for long distances. This deposit was formed by peneplanation and

subsequent weathering of the land surfaces during the later Tertiary, producing a layer of loose, insoluble materials. As a result of the several rejuvenations discussed on early pages, the streams could carry more detritus which was dropped on reaching lower levels. This process was repeated again and again with subsequent uplift and erosion. The sediments now are removed from places which have been subjected to severe erosion but are nearly always present in places where streams are too weak to handle the residue. Especially is this true in the Pearisburg area where underground drainage takes care of so much of the water, that surface erosion is lagging far behind subsurface weathering.

### STRUCTURAL GEOLOGY

The sedimentary rocks of this county have been extensively folded, and these folds have their elongated axes roughly parallel and trending east by northeast. Many of the upper layers have been worn away by erosion, so that narrow, parallel belts of outcrops, trending in the same direction as the folds, are the common thing. Harder rocks, such as sandstones and quartzites, have resisted erosion and hence are the mountain makers. The valleys between them are usually carved in softer or more soluble strata, such as shales or limestones.

The folds are, for the most part, continuous and may be traced for miles. The same may be said of the faults, which closely follow the axis of greatest folding.

Folding has tended to increase the thickness of the formations along the crests of the structures and, as a consequence, added strength has been given, so that the formation may take up still more of the stress. These beds are, of course, competent, such as the Clinch, Shenandoah, etc. Non-competent beds, such as the Sevier and the Russell, develop smashed, intensely folded areas between the stronger layers. Drag folds become pronounced and small displacements and shearings are common.

The big Peters Mountain fault runs along the north edge of East River and Peters mountains, just outside of Giles County, and brings Cambro-Ordovician rocks in contact with upper Devonian strata. A smaller fault parallels the East River-Peters Mountain break, and runs north of Wolf Creek. It crosses New River just above the rapids at Narrows and proceeds eastward,

passing just north of Kimballton. It seems to be a single fault east of New River but westward it is generally in two steps. In this paper, this fault will be called the Wolf Creek fault. Near the Narrows, Giles and Romney rocks are brought by this displacement in contact with the Shenandoah limestone.

The Saltville fault parallels the southern boundary of the county. It runs through Poplar Hill, Staffordsville, and a little south of the crests of Buckeye and Spruce Run mountains. Everywhere on the southerly side of the fault is the Shenandoah limestone, but on the north, there are Ordovician, Silurian and even Devonian rocks in various places. It seems to be a two-step fault in Buckeye Mountain.

All of the above mentioned faults are of the thrust type, and in each case the older rocks were thrust over younger ones from the southeast. The dips, then, on the southerly side are regularly south-south-east ward, rarely more than  $25^{\circ}$  in the case of the Saltville fault, and seldom exceeding  $35^{\circ}$  in the other two previously mentioned breaks. Other faults of Giles County are of the normal type, and are too small to be named, being ordinarily confined to a single member of one formation, with displacements of less than fifteen feet.

Walker Mountain is formed by the upturned edges of the Clinch and Bays formations to the south of the Saltville fault. Buckeye and Spruce Run mountains are formed by the upturned and south dipping Rockwood, Clinch and Bays on the north side of Saltville fault. The crests are on the south limb of an anticline whose axis lies just north of them. In their south slopes these mountains still preserve enough structure to show that they are the remnants of a syncline which was broken by the fault. Thus the strata on the south side of the fault were thrust up many hundreds of feet so that Shenandoah lies against Rockwood and Clinch. This displacement carried the south limb of the syncline and the succeeding anticline (whose axis was between Buckeye and Walker mountains) so high that they were all eroded in the pre-peneplain periods of erosion (probably early Mesozoic time). Walker Mountain, then, is the southern limb of the anticline with the strata dipping away to the south.

Pearis and Angels Rest mountains are opposite sides of a synclinal structure pitching off to the west by southwest, so that Mill Creek is flowing in an erosion widened, structural valley.

Butt Mountain is another part of the same structure pitching in the opposite direction, east by northeast. Between these two summits the structure was so high in pre-peneplain times, that the hard layers, Rockwood and Clinch, were eroded off together with the less resistant ones down to the Shenandoah and Chickamauga limestones. New River found its way across the structure at this place. The roots of the syncline can still be seen in these rocks in the vicinity of Ripplemead.

The limestones making up the valley areas are of course influenced by the above discussed structures, yet in most places the dips are not extreme. However, north of Bane, where the anticline between Pearis Mountain and Buckeye Mountain is folded highest, there is an area where many small pronounced structural features occur, but these have previously been discussed under the heading of the Russell formation.

Sugar Run Mountain and Pearis Mountain converge toward Flat Top Mountain because they stand up on account of the hard layers in the above discussed anticline, which is pitching steeply westward. Flat Top is then the descending crest of this structure as it goes down carrying on its summit Clinch, Rockwood, Giles, Romney and Kimberling.

## ECONOMIC RESOURCES

### Coal

Giles County may be regarded as a block of older Paleozoic strata separated from younger rocks, on the north, by the Peters Mountain fault, and on the south, by the Walker Mountain fault. For this reason, coal is not found in Giles County, although semi-anthracite coal of good grade is mined but two miles to the south of the Walker fault, in the Cloyds Mountain area of Pulaski County.

### Oil and Gas

The possibility of finding either oil or gas in the rocks of Giles County is remote, indeed, and so far as could be discovered there has been no drilling for either of these products.

The strata of this area are so deeply dissected, so complexly faulted and mashed, and so intensely folded that any oil or gas once imprisoned has long since escaped. However, since none of the residual products of the natural distillation of hydrocarbons are found, it is doubtful if they were ever present here.

### Manganese<sup>22</sup> Historical Sketch

The manganese deposits of Virginia have been worked at various times since 1834. However, previous to 1917, no work of a commercial nature was attempted in Giles County. In this year, the Stange mine was first operated and various other smaller prospects in the county were exploited, due to the increased demand for domestic manganese ores on account of the War. When the armistice was signed, work ceased at once on most of the mines, but the Stange prospect was operated until June 1, 1919. This mine, which is one of the most important in the state, is no doubt the prospect described by Boyd<sup>23</sup> some forty years ago as follows:

"Manganese ores seem to be confined almost exclusively to the Oriskany measures. In fact, the iron ore of these rocks frequently gives way almost entirely to oxide of manganese.

"At one point in these rocks on Flat Top Mountain, near the line between Giles and Bland counties, the ore was found in great purity, giving the following measures, etc.: Trend north 70° east, dip 60° north 20° west, containing valuable quantities of manganese disseminated heavily through the sandstone, five hundred yards in length, gradually becoming impregnated with iron as you approach the eastern end. The apparent width of the ore strata here is extraordinary, and may be owing to a duplication of strata from end pressure, or flexure, or a mere fold. It is 240 feet through. Elevation above the water level in Kimberling Creek is 1200 feet; vein would no doubt strip well.

"Analysis of Manganese Ore as follows:

"Red oxide of manganese ( $Mn_2O_3$ ?)	84.34 (a)
Oxygen (O)	3.73 (a)
Protoxide of Cobalt (CoO)	.68
Alumina ( $Al_2O_3$ )	1.80
Lime (CaO)	.32
Silica ( $SiO_2$ )	.21
Baryta (BaO)	7.21
Water ( $H_2O$ )	1.71

(Signed) H. Dickinson."

<sup>22</sup> The material incorporated under this heading has been derived in part from Bull. No. 23 of the Virginia Geol. Sur. by Stose, G. W., and Miser, H. D. and also from private sources of information.

<sup>23</sup> Boyd, C. R., "Resources of Southwest Virginia," pp. 147-148. John Wiley and Sons, New York, 1881.

This description, even in the light of present knowledge, may be regarded as a very good one, and to Boyd must go the credit for first mentioning the manganese deposits of Giles County, at least, in writing.

It may be interesting to digress here long enough to mention the method of discovery of the value of manganese in the manufacture of heavy ordnance pieces. According to Judge Bernard Mason<sup>24</sup> of Pearisburg, many of the large guns used by the South, in the Civil War, were made from iron ore obtained from Giles County and vicinity. This ore contained some manganese, but this fact was either unknown or disregarded by the manufacturers. The fact that the southern canon stood up better under heavy service was known, however, and the war being over, an investigation was made. The results showed that manganese had imparted extra strength to the steel.

#### The Stange Mine

The Stange mine has marketed slightly more than 2000 tons of ore during the course of its operation. The workings are on and near the crest of Flat Top Mountain, and the boundary between Giles and Bland counties actually passes through the mine. There are three principal cuts: the North cut, which is on the north side of the crest, trends east and west, being about 250 feet long by 60 feet wide and 30 feet deep. The South cut is 600 feet in length and follows the face of the mountain. The Middle cut runs northeast from the South cut about 150 feet and is some 40 feet in width by 20 feet in depth.

The veins and pockets of ore vary greatly in size, the ore being distributed through all the sandstone revealed in the openings, but very unevenly. One ton of ore of market grade can be derived from four to five tons of the ore-bearing sandstone.

The ore as mined by B. T. Johnson and sons, as well as by Mr. Suffern, was either picked up on the surface or mined by hand in open cuts and was then hand-picked for marketing.

Mr. Stange later operated the mine by means of a steam shovel, and then hauled the ore more than a mile to the washing plant on Ding Branch of No Business Creek. The plant consisted of a double log washer and a picking belt. After the ore was run

<sup>24</sup> Private conversation.

through the washer, the concentrates were hauled in trams from the plant to the base of Wolf Creek Mountain. From this point, the ore was carried to First Ford station by means of an incline railroad. Here, it was transferred to standard cars for shipment. Of necessity, this transportation method greatly increased production costs.

The deposit is in the Giles sandstone which is probably of Oriskany age. The sandstone appears on the surface as well as in the workings. There are pockets of ore and sandstone fragments up to ten feet in width, which extend down to some twenty-five feet. These are thought to be zones of fissuring in the anticlinal arch of sandstone, which have become impregnated with ore formed by the accumulation of residual materials in the fissures as the rock weathered.

Scattered masses of ore at the surface indicate that the deposit extends east and west some nine hundred feet and north and south a little over three hundred feet. A drill hole seventy-two feet in depth is said by Mr. Stange to have found the ore continuous at least to that depth. The minerals are manganite, pyrolusite, psilomelane, the last named being most common at the surface. Pyrolusite is the chief mineral found at depth. It is of a fine grade, suitable for metallurgical purposes. The mine has by no means been exhausted, and future developments may be expected as soon as present transportation difficulties are overcome.

#### Other Prospects

No other prospect for manganese in Giles County approaches the Stange mine in size or possibilities. Pyrolusite float can be found here and there almost any place in the county. On account of this fact, when the war boosted manganese prices, attempts were made to develop a number of prospects which were without commercial value.

#### Laing Prospects

This prospect is two miles northeast of the village of Newport. Newport is a village in the southeast corner of Giles County, a mile south of Sinking Creek and 7-8 miles east of Eggleston. A group of openings has been made on a hill top about a mile north of Sinking Creek. The elevation is 2600 feet and seems to mark the level of a former peneplain, now largely destroyed. The prospect is underlain by Shenandoah lime (Knox dolomite

of Stose and Miser) and the ore is in the residual clay and chert of this formation. An overthrust fault here has brought these older rocks in contact with sandstones of probably Oriskany age which appear a little higher on the mountain side. Very little actual work has been done here.

#### Simpkins Prospects

This prospect is two and one-half miles west-north-west of Interior Station on the Potts Valley branch of the Norfolk and Western Railroad. This branch leaves the main line about a mile below Ripplemead and runs up Stony Creek past Kimballton almost to the northeast corner of the county. The openings are on the crest of a spur of Peters Mountain at an elevation of 2800 feet, and the ore appears to be in the fractured zone of the southwest end of the local syncline. The formation in which the ore is found is the Giles, which is here a buff colored, much fractured sandstone. Psilomelane is the ore. Transportation facilities are good since the prospect is less than a mile from the railroad, but there is not enough ore in sight to warrant exploitation.

#### Stowe Mine

This mine is on the southeast slope of Piney Mountain, four miles to the southwest of Narrows on the Norfolk and Western Railway. The openings are all shallow pits, on or near the surface of a bench which is 2400 feet in elevation. This probably represents the old valley floor peneplain of the New River System.

The ore is in shaly sandstone and clay which appears to be of Giles age. About fifty tons of ore, running 32% manganese have been taken from the mine. This mine can only be worked at a profit when the demand for manganese is greatly increased.

#### The Bane Prospect

This prospect, which lies just south of Walker Creek at Bane, seems to be little known. However, this prospect is probably the only one in the county (the Stange mine excepted) which has possibilities favoring development in the future.

The ore, which occurs in the residual clay and chert overlying the Shenandoah limestone, is pyrolusite. The area over which the ore appears on the surface cannot be less than forty acres, and, according to local information, several small pits found the ore not decreasing in quantity at a depth of five feet. The

surface mantle of soil and chert contains the ore, hence a wasner would be necessary to prepare the manganese for market.

The nearest point where shipment could be made, is Pearisburg Station, which is some eight miles distant, too far to warrant exploitation at present. However, should a railroad be run up Walker Creek Valley, this prospect would at once become of considerable value, since the quantity of ore is large and can easily be worked by steam shovel.

#### The Hare Prospect

This prospect is one and one-half miles north of Chapel Station on the New River, Holston and Western Railroad. Two openings have been made, both in the Oriskany member of the Giles, which are about forty feet long by eight feet wide by fifteen feet in depth. Some psilomelane has been mined but the sandstone has been only partially replaced by this mineral and brown iron ore. The latter may become of importance since a pit farther north reveals the ore to be some fourteen feet thick in the Rockwood formation.

#### Other Locations

Manganese is also reported from many other localities. The Beamer prospect is about a mile east of the Hare prospect mentioned above. No Business Creek prospect is three miles south of Chapel station over Wolf Creek Mountain and while little work has been done here, surface indications suggest a considerable deposit of manganiferous iron ore. Other prospects, similar in nature to the Stange mine, occur farther to the east of this deposit on the same ridge. The Johnson prospect and the Thompson place are both Flat Top prospects somewhat more than a mile to the northeast of the Stange mine. In both places, the ore is low in grade and occurs only in small amounts. However, some twenty-five tons have been shipped from the Johnson mine.

Manganese float is also found in Short Mountain, in the vicinity of Narrows, in the Doe Mountain region, near Newport, and in the Spruce Run Mountain tracts. These prospects have not been exploited and if any ore has been shipped, it has been hand picked from the float appearing at the surface and is almost negligible in quantity.

### The Origin of Manganese Ores in Giles County

The important manganese deposits of Giles County occur in clays, sandstones and cherts. Chert, in the Shenandoah, is often stained black by the oxide of manganese which in some cases is present in sufficient quantity to warrant the name of ore. Chert which has been broken into small fragments is often cemented with manganese oxide or even replaced by it. Both the chert and the manganese, being relatively insoluble, have been left behind as residual products of the weathering of the limestone. Some of the deposits are near fault contacts, the concentration being due to the free circulation of ground water in the brecciated zone. However, if we except the deposit near Bane, described above, prospects in the Shenandoah are small and of no great value; in fact, the only mine of this type which has been worked in the county is the one near Newport. It is rather interesting to note that, so far as could be ascertained, ore of this type occurring in the residual clays of Giles County does not show any evident connection with the chert found in association. The connection, however, is obvious in the deposits of the other counties in southwest Virginia.

In Giles County by far the largest deposits of manganese occur in sandstones of the Giles formation or in the unconformably underlying Rockwood sandstones. Crests of anticlines seem to be the favored position for the accumulation of these deposits, due to the fact that these resistant beds, when bent, developed fractures wherein ground water could easily circulate.

Many of the prospects are unique in that they occur on Mountain tops, such as the Flat Top Mountain prospects. Obviously, segregation must have taken place when the present elevation of some 3000 feet was part of a peneplain which was not very high above sea level. Other deposits occur on benches on the flanks of the main ridges. These also were segregated when the present elevation was but a part of a smaller, and later peneplain than that which was developed in Cretaceous time. Of the bench type are the Carrie, Laing, Simpkins, and the Spruce Run Mountain prospects mentioned above.

The association of these ores with particular formations seems to indicate that the manganese was deposited in greater quantity in certain beds than others, yet only disseminated thinly; and that it has been concentrated into its present state, by solution

and redeposition by circulating ground waters as the rocks weathered.

The manganese ore of the Shenandoah was probably widely scattered in the basal portions, originally as a carbonate. Here it was dissolved by ground waters. Solution channels, caving, or folding caused brecciated zones, in which the ore was redeposited in a concentrated form. The interstices were thus filled with ore, and the silica of the chert was in some cases partially replaced by the manganese oxide.

In a similar manner, the ore which is found in the Rockwood and Giles formations was originally disseminated in the basal Giles. The manganese was concentrated by descending, circulating waters and deposited as the oxide near the bottom zone of surface weathering.

The Oriskany iron ores of Virginia have been regarded by Watson<sup>25</sup> and Holden<sup>26</sup> as having been derived from the iron bearing minerals in the Devonian shales overlying the Oriskany. These minerals were dissolved by carbonated waters during weathering and redeposited in lower levels. Watson suggested that the manganese deposits in these rocks might have had a similar origin. Accordingly, he collected a sample of unaltered shales which overlie the manganese of Bland County to determine the absence or presence of manganese. Although the analysis showed 4.54 per cent. iron oxides, no manganese was found.

The absence of manganese in the particular sample of shale collected has been thought to have made this theory untenable. However, despite this fact, we are inclined to the opinion that at least some of the manganese was originally disseminated in the overlying shales as well as in the sandstones of the Giles formation. The reasons for this view may be stated as follows: first, some of the deposits occur well up in the Giles sandstone, so that derivation, in entirety, from the same formation is rather unlikely, and, second, if the iron deposits which are so wide spread in the lower measures are derived from the Devonian shales, whose analysis shows but 4.54 per cent. iron oxides, might not the manganese, whose quantity is negligible in comparison with that of the iron, have, at least in part, the same source, and yet not be detected in the analysis, especially, of a single sample?

<sup>25</sup> Watson, T. L., "Mineral Resources of Virginia," pp. 408-410, 1907.

<sup>26</sup> Holden, R. J., U. S. Geol. Survey Bull. 427, pp. 67-68, 1910.

### Iron

Iron ore has been mined in Giles County, and will, in the future, constitute a more important economic resource than it has in the past or does at present. The ores may be divided into three classes: Those found in the Oriskany horizons, the Clinton or Red fossil ore of the Rockwood and the ores found in the lower Paleozoic limestones.

The Brown iron ore is the type usually found in the Oriskany measures. Boyd<sup>27</sup> estimated that ten per cent. of these rocks were iron, but the deposits are of such a local nature that this estimate seems much too high. The most conspicuous beds are found on Buckeye, Butt, Salt Pond and Flat Top mountains. There is also a large deposit on Wolf Creek Mountain, which Boyd thought would yield 300,000 tons of ore, which would run over sixty per cent. metallic iron. Boyd was rather prone to exaggerate and but little has been mined here. At Interior, some mining of Brown ore in Oriskany measure has recently been done, and since the railroad has solved transportation problems, it seems likely that more ore will be mined in the future, as the reserves here are quite large.

The source of these ores has been explained in the discussion of the Stange mine. The Devonian was a period during which much iron was deposited,<sup>28</sup> as is shown by the fact that shales overlying the Oriskany sands will run five per cent. iron content. The concentration of these ores in fracture zones in the lower sandstones is thought to be the origin of the local Oriskany ores.

Hematite ore is found in the Clinton (Rockwood) formation wherever it is exposed in Giles County. The ore is usually the richest in the lower layers just over the Clinch. This is especially true where the Rockwood is the ridge maker, as in these cases the iron of the upper layers has been leached out and concentrated in the fractured lower layers, which overlie the nearly impermeable quartzite below.

The ore is both fossil and granular in type. The fossil ore is made up of aggregates of broken fossils, which were originally calcium carbonate, but which have now been replaced by ferric oxide, some of which was always present in the formation, prob-

<sup>27</sup> Boyd, C. R., "Resources of Southwest Virginia," pp. 144.

<sup>28</sup> Emmons, W. H., "Principles of Economic Geology," pp. 295.

ably filling cavities. The granular ore (which is usually subordinate to the fossil type) is made up of aggregates of quartz grains like flaxseed in shape, about which the iron oxide has been deposited. In the Clinton epoch, iron was deposited in large amounts throughout much of eastern North America. This ore was carried in solution as bicarbonate in the presence of carbon dioxide. When the excess carbon dioxide was removed, ferric hydroxide was either precipitated due to oxidation and hydrolysis, or on account of the iron bacteria, which according to Harder<sup>29</sup> are always active in its accumulation.

The Bays Formation (Upper Ordovician) is often ferruginous, and Bassler has suggested that at least some of the iron of the Clinton is due to the erosion of the Bays, together with the solution of its iron content, and its subsequent concentration in the Rockwood. In a like manner, much of the Devonian ore may be due to the erosion of the Rockwood and the later deposition of the iron content in the Giles sandstones and shales.

The deposit of this type of ore over the entire flat summits of Angels Rest and Pearis mountains may sometime be developed. There are many thousands of tons of poor grade ore in this deposit which might be mined by steam shovel. The small iron content and the lack of any facility to get the ore down off the mountain prevents the exploitation of this ore body.

Many of the Brown ore deposits in the Cambro-Ordovician limestones appear to have been formed rather recently, probably during Tertiary times. (Tertiary fossils have been found in these deposits.)<sup>30</sup> These ores are alteration products of iron carbonate and pyrite, which in turn originated by replacement of the limestone. The ore often is found filling fissures and concentrated in fracture zones. From the structural position of many of the ore bodies, it seems evident that the deposits were made when the country had reached a topographic state not vastly different from that existing today.

The best exposures are at Johnson's near Chapman's Ferry, and at the mouth of Big Stony Creek. Scattered out-crops of this ore are found over the entire county. Usually the stratigraphic position of the ore is near the contact of the Shenandoah with the Chickamauga.

<sup>29</sup> Harder, E. C., "Iron-depositing Bacteria and their Geologic Relations," U. S. Geol. Survey Prof. Paper No. 113 (1919).

<sup>30</sup> Eckel, E. C., U. S. Geol. Survey, Bull. 400, pp. 145.

Thus while the county has a good deal of iron ore and much more ferruginous rock which may some day be leached to make valuable ore, yet there is really no deposit of iron ore known that can compete with the producing regions of the United States.

### **Limestone and Cement**

The limestones of Giles County are of great importance since they may be used either in the manufacture of lime or cement, or as building or road making stone. The New River Lime Company has a quarry to the northwest of Ripplemead, along the river, from which is taken some forty car loads a day. Clay Mason has a considerable lime making establishment across and a little upstream from this quarry. At various times, the limestone has been used in other places but the industry has not been developed nearly to the limits of its possibilities. Cement could be manufactured quite to advantage here, since the Chickamauga exposures are all well served by railroads, and the necessary shale is usually found close at hand in the Sevier formation.

### **Clays and Shales**

These are of little importance here and have not been exploited.

### **Sands and Gravels**

These belong in the same category as the above list. Some sand is taken from the New River for local use, but it promises no importance. Tertiary gravels occur, but are of little use, being composed of large boulders, of cobble stone size, for the most part.

### **Water Supply**

As would be expected in a mountainous, limestone area, receiving considerable rainfall, there is an abundance of water. This supply is very liable to contamination, however, on account of the great development of under-surface drainage. There are several places along the New, where water power could be obtained by tunneling, but an abundance of cheap electric power, due to the nearness to the coal fields, has so far, hindered this. Sulfur and mineral springs occur at Eggleston and at other points.

### Soils

For the most part in this area, the soils and the rocks from which they are derived, are equally differentiated, so that the areal map may be followed with considerable accuracy. The sandy soils derived from formations such as the Bays and the Clinch are of no importance for agricultural purposes. For the most part, shale does not disintegrate into a fertile soil; however, the Sevier shale contains enough calcareous material to make it quite productive. This formation, however, usually outcrops so high and on such steep slopes that it ordinarily cannot be used. The Chickamauga ranks the highest as a soil producer and is responsible for the rich farming lands of the Pearisburg area. The Shenandoah limestone also disintegrates into a fairly fertile soil but it also leaves behind it a mantle of the insoluble chert which makes cultivation difficult, but not impossible.

No doubt the soils of the county constitute, at present, the most valuable geologic resource available.

### RESUME OF GEOLOGIC HISTORY

As has been mentioned in the introduction, the area under discussion lies in that division of the Appalachian Highlands,<sup>31</sup> known as the Appalachian Valley Province. Giles County is situated at the extreme southern end of the Middle Section of this province. In northwestern and in the central western portions of Virginia, there is no great difference in the stratigraphic succession or in the lithology of the Ordovician and Silurian strata. In the area comprising most of southwestern Virginia, however, a new factor is introduced in the study of these same rocks. Ordinarily, rocks deposited synchronously in comparatively small areas exhibit no great differences either in fossil fauna or in lithologic aspect. In the division of the state mentioned above, the rocks differ in different areas, in both of these respects. In the eastern portion of the great valley, the development of the Ordovician strata is entirely different from that found in the westernmost portions of the state. In studying the various sections, these discrepancies in apparently the same age of strata are encountered in traverses made across the valley rather than in directions paralleling the length of the valley.

<sup>31</sup> Physiographic Divisions of U. S. Ann. Assoc. Amer. Geog. Vol. VI., pp. 19-98.

The theories for this distribution of strata in separate areas will not be developed in this paper any more than to mention that Ulrich and Schuchert,<sup>32</sup> in their *Paleozoic Seas and Barriers*, have advanced the well founded idea that the area of the Appalachian Valley during Ordovician times was divided longitudinally into several narrow troughs, which were rather effectually separated, one from the other and that the observed differences in sedimentation and faunal life may thus be explained.

The area covered in this survey lies entirely within a single one of these "troughs" but as one ascends the New River and comes to the Giles-Pulaski County line, there is noticed at once a marked difference in faunal life and lithologic aspect. The details cannot be discussed here but it might be interesting to note that the Clinch formation in Gap Mountain, is composed of three distinct quartzitic ripple making layers, while at the Narrows, a scant twelve miles to the west, there are but two of these layers and one of these is not distinct.

The Appalachian series of folds, probably trace their origin to pre-Cambrian times. Walcott<sup>33</sup> demonstrated the existence of a long trough, which during Lower Cambrian times extended from Alabama northeast to Labrador. This was no doubt what we would call a geosyncline and was within the southeastern border of a large Algonkian continent. It was during this time, that the impure limestones and variegated shales of the Russell formation were deposited. At varying intervals, the seas were deep and then again they were shallow, until in Middle Cambrian time, the Appalachian trough was almost drained of its sea. However, long before the close of this epoch, a new period of subsidence was inaugurated, and the sea became gradually deeper until in Upper Cambrian time it was beyond the Adirondacks and had made connection with the Atlantic by way of the restricted Appalachian trough.

For the most part, the Upper Cambrian seas laid down great beds of limestone, which are usually dolomitic and non-fossiliferous. These facts seem to indicate that the Shenandoah limestone, which was laid down at this time, was deposited at a considerable distance from the shores and in waters which were of a considerable depth. Chemical precipitation will be regarded

<sup>32</sup> Ulrich, E. O. and Schuchert, Charles, "Paleozoic Seas and Barriers in Eastern North America." N. Y. State Museum Rept., Bull. 52, pp. 633-664.

<sup>33</sup> Walcott, C. D., U. S. Geol. Surv. Bull. 81.

as the main source of the material which composes it. Between the limestones of this time and those of Beekmantown age in the area under discussion, the difference is very slight and it must be regarded that the sedimentation went on almost uninterrupted from the beginning of the Upper Cambrian to the close of the Beekmantown. We will regard the deposition of the Shenandoah limestone, then, as having taken place during this interval. The close of the Beekmantown marks the beginning of a new arrangement in Eastern North America.

A new fold was developed, nearly parallel with, and a little within the western border of the original Lower Cambrian trough and another fold, mentioned before as having emerged early in Middle Cambrian time, was accentuated. Between these two folds, a trough was formed which extended from Alabama to Quebec. It is doubtful, however, if this trough was ever again completely submerged after Beekmantown time. Ulrich and Schuchert have named the western one of these two folds, the Appalachian Valley Barrier, and the eastern one was named the Chilhowee Barrier. The Lenoir bay, which was the southern third of the space between the two folds, occupied a synclinalorium containing several disconnected folds, which were high enough to affect the direction of currents, and consequently the character of sedimentation. In a general way, these deposits may be divided into an eastern trough (Athens trough) and a western one (Knoxville trough). The members of each overlap or grade into each other on account of differential warping.

The area under discussion lies in the Knoxville trough. The development of the Chickamauga limestone here indicates that there was at the time of deposition of its bottom layers enough warping to permit portions of the older Shenandoah to be subjected to erosion. The breccia which goes to make up the lower layers of the Chickamauga formation in this area is made up of angular fragments of chert which is identical with that found in the Shenandoah of today. That this chert in the breccia was derived from the older formation is evident and that it was carried but a short distance is evidenced by the fact that the fragments are always angular and in the upper layers of the breccia are seldom in contact one with the other.

The Chickamauga of this area, that is, of the Knoxville trough, contains a fauna wholly distinct from that of other Chickamauga

series, one of which has its greatest development in East Tennessee. In this (the Pearisburg area) locality, however, the Chickamauga embraces every important member of the formation as developed in Tennessee. There is evidence of only a small unconformity between this formation and the Shenandoah, and yet, if we have correctly correlated these strata, a considerable time break exists. This is no doubt represented in part by the breccia described above.

Following the Chickamauga is the Moccasin limestone, which is calcareous near its base, but which becomes very arenaceous near the top. This formation is clearly a gradational one representing the time between the deep seas in which the Chickamauga was deposited and the shallow seas wherein the Bays was laid down. It is due no doubt to the gentle uplift which began in the time just preceding the early Trenton. In the eastern trough we have, as the equivalent of the Moccasin, the Tellico sandstone. After this time, the Sevier formation was deposited quite uniformly in both troughs. The Sevier in its various divisions is equal to the upper Utica, and the Eden, and as would be supposed, grades from calcareous at the base to arenaceous at the top. The Sevier (as well as the Moccasin) may be regarded as an intermediate formation fore-running the Bays.

At about the end of the Trenton, the troughs were elevated quite rapidly and as a consequence, communication with the Atlantic was cut off at the south where the elevation was the greatest. At the same time, the middle portions of the Lenoir Trough sank and permitted the waters from the Mississippian sea to invade. The result of this revolution is the Bays and Clinch sandstones as well as the lower and non-ferruginous shale members of the Rockwood. The southern end of the trough continued to be uplifted as is shown by the fact that of the three mentioned formations, the Bays extends farthest to the south, the next, not quite so far and the third, the Rockwood, falls still short of the Clinch. In spite of the fact that there is an unconformity between the Rockwood and the Giles, (indicating uplift and erosion in Giles County) when Devonian sediments were laid down, the seas were again deeper in this area than off to the south. This is clearly shown by the fact that these sediments are but 25 feet thick at Chattanooga yet are nearly 5000 feet in thickness on the New River.

Mississippian and Pennsylvanian rocks were laid down in Giles County, but have been subsequently eroded. There is no direct evidence for making this assertion, but Pennsylvanian rocks are found on either side of the county, and since faulting has so raised the entire area that Shenandoah lime is in contact with Kimberling shales, there has been every opportunity for erosion to have removed these later Paleozoics.

After this time, the uplift was rather steady and Giles County becomes a land mass. Folding and faulting were not pronounced in the Mesozoic, and by the end of this era a great peneplain had been reached. However, in Oligocene time upwarping began along the Appalachian axis and continued throughout the epoch. As a result, the stream gradients were increased and erosion began apace. As a result, the Tertiary Gravels were deposited in those areas where the stream currents were abruptly checked. The uplifts in the several periods of movement were continuous, but gradual, as is evidenced by the fact that the New River has been able to maintain its course through the ridges which are due to the hard layers.

The rocks of Giles County suffered no close folding during the Paleozoic because, while unconformities can be found, the angular type is inconspicuous. There are no typical continental deposits in the county unless we except the Tertiary Gravels mentioned above. The Clinch has been regarded as a delta deposit and its shape and lithologic character in many areas seem to confirm this view. Here, however, the presence of a marine fossil, (*Lingula cuneata*) as well as shaly layers indicates that the formation is at least semi-marine, and if it is a portion of a delta deposit, it is the extreme outer edge of such a formation.

Mud cracks are common in many of the formations showing shallow seas, yet marine fossils are also found in these same horizons. Rapid changes of conditions are shown by the presence, in some places, of limestone breccias, as well as fissile shale partings in the great limestones.

The chert in some of these limestones seems to be a surface feature, as deep quarries run out of the chert zone. The presence of chert everywhere in deep caverns may or may not be regarded as an additional proof of the surface character of the chert. Calcite is also secondary in these limestones and is regarded as Mesozoic or Tertiary in age, having formed everywhere in the

fractures developed in the competent limestones during the time of folding. That it is younger than the chert, is often shown in specimens where the chert, as well as the limestone, has been cut by a calcite vein. Hence some of it must be very recent. The age of the iron ores has been discussed, but it may be added that they sometimes seem to be both secondary and primary.

In conclusion, it should be said that this paper has but merely touched upon the geology of Giles County. Scores of problems stand out boldly bidding for solution, while many others lie half concealed and shyly invite attention. Not the least of the problems available are those connected with the ancient life. In this area, the fauna is different from the fauna in the next county to the south. The comparison of the development of contemporaneous life in isolated basins, which are yet not far distant from each other, may go a long way in the solving of some of the problems of evolution. When this work is at last undertaken, the area about Giles County will be a geologist's "happy hunting ground."

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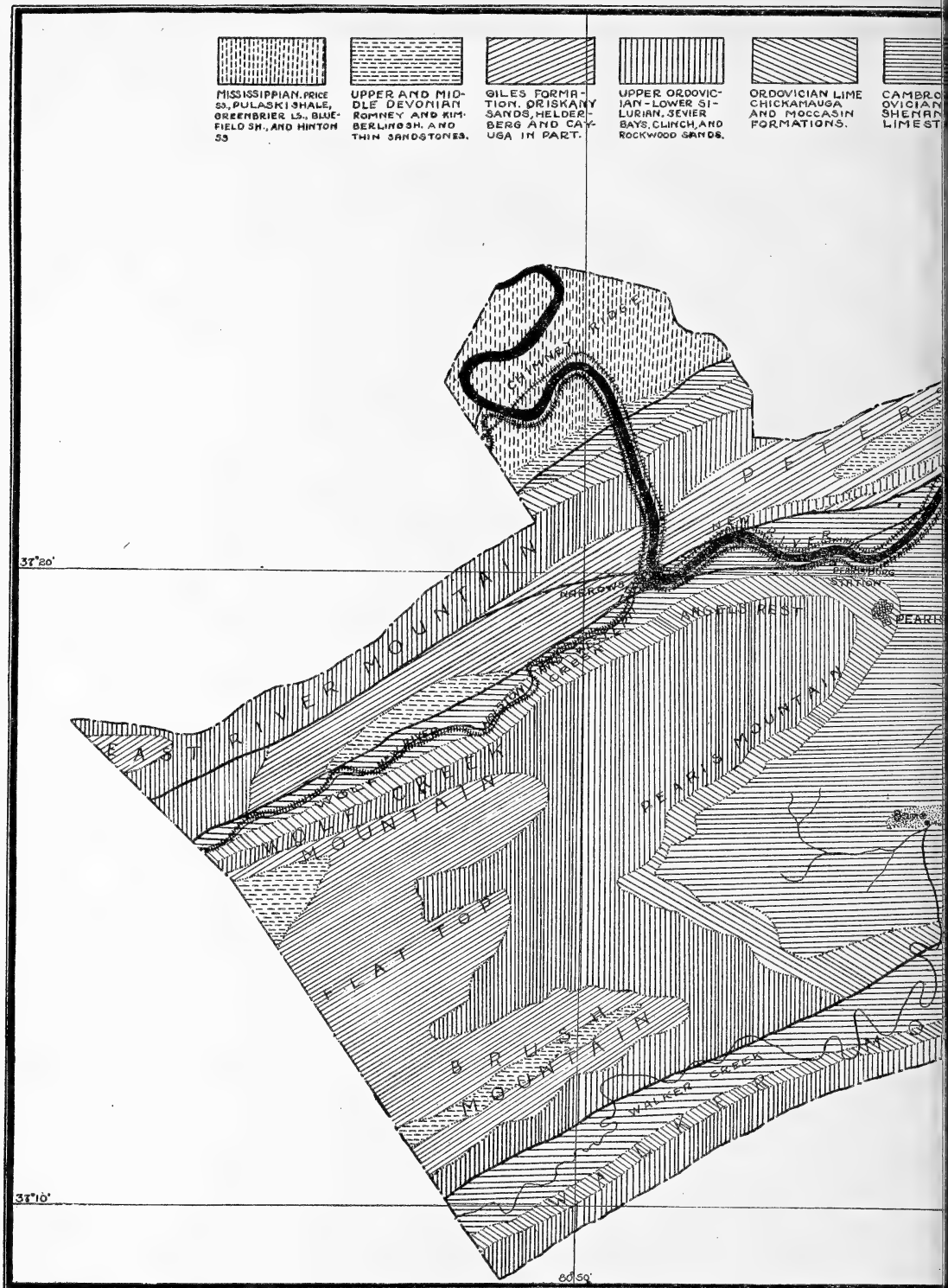
### PLATE XLIII

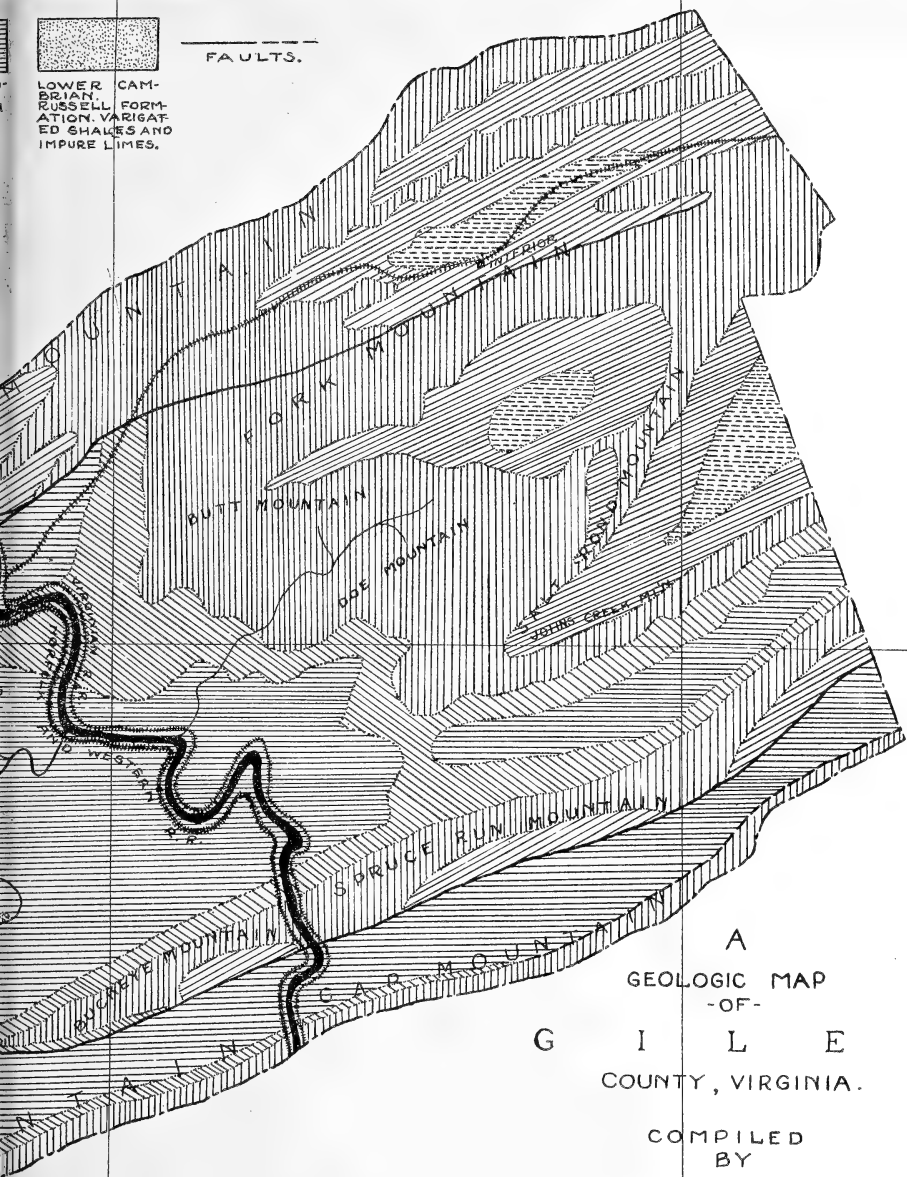
#### Note on sources of Geologic Map of Giles Co.

This map was compiled from (1) Watson's State Geologic Map of Virginia, (2) a map issued with Stose & Miser's "Manganese Deposits," (3) an old map by J. J. Stevenson, published in Transactions of Amer. Philosophical Society and (4) the work of the Class of 1922.

The manuscript maps by other classes were not used because this map was completed before the accompanying manuscript had taken its present form. The additional data on other MSS. maps would not make much difference in a map on this scale and refinement but in a larger scale map with formational units several areas of Romney, Giles, and Rockwood must be changed. The authors.







A  
GEOLOGIC MAP  
-OF-  
G I L E S  
COUNTY, VIRGINIA.

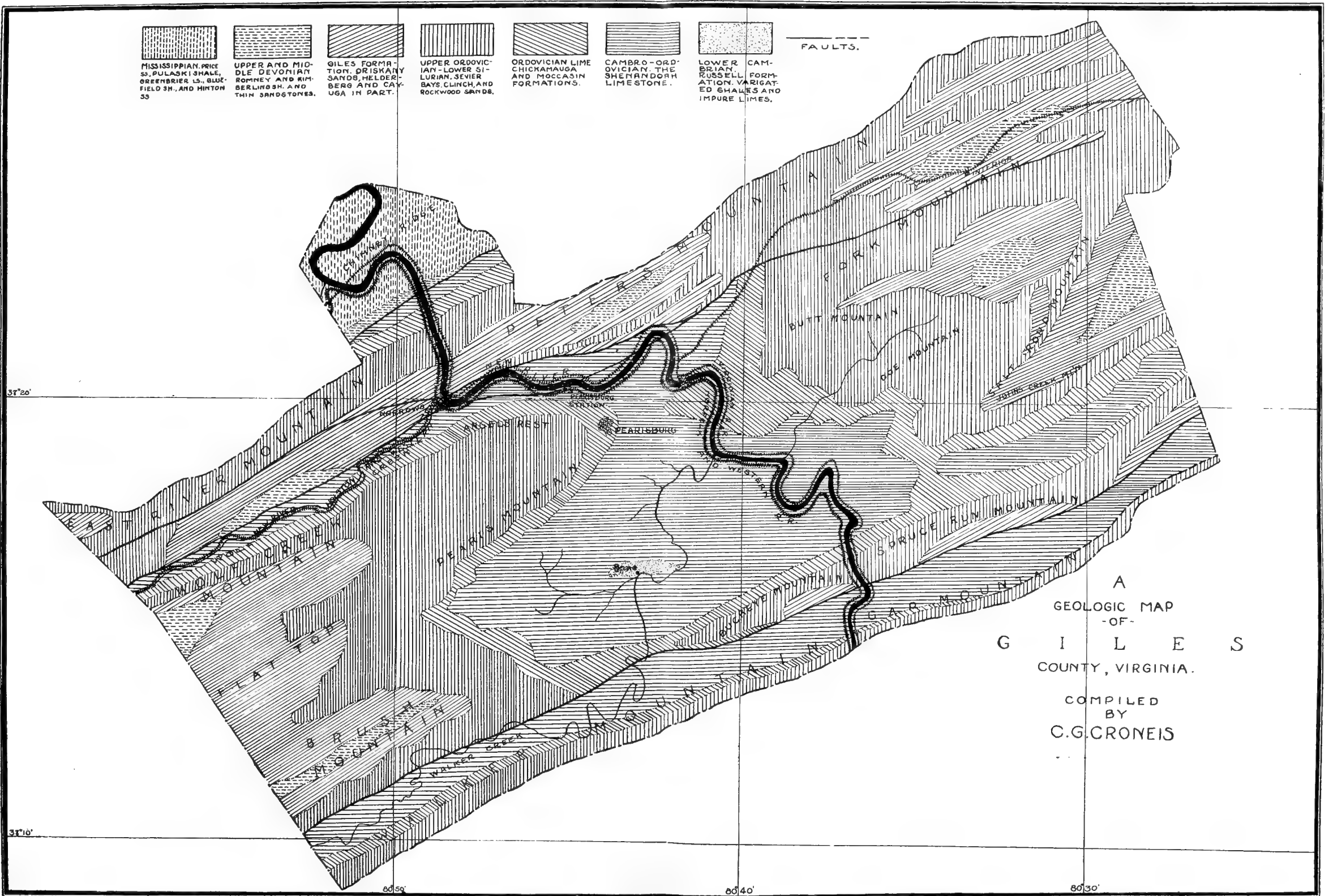
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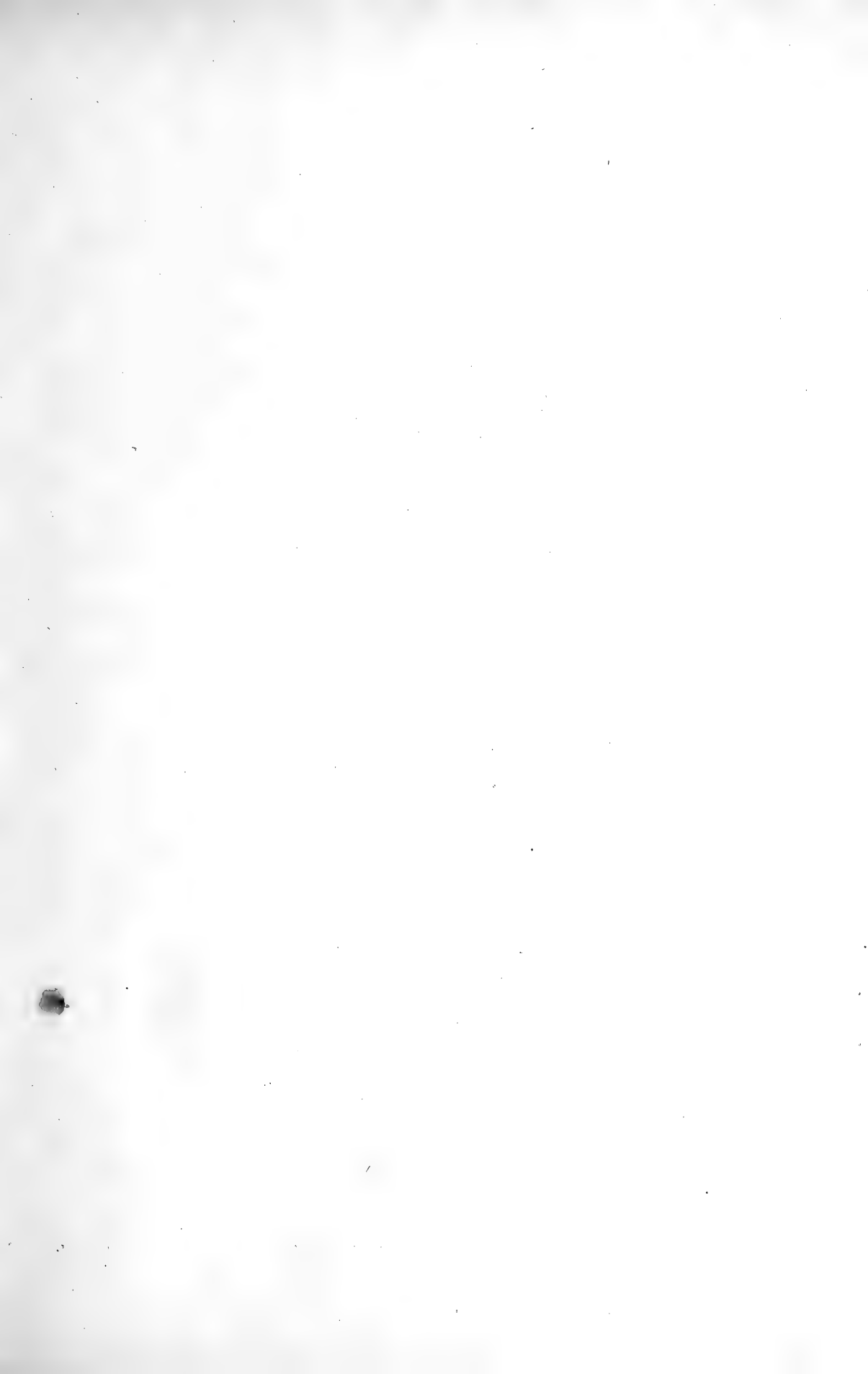
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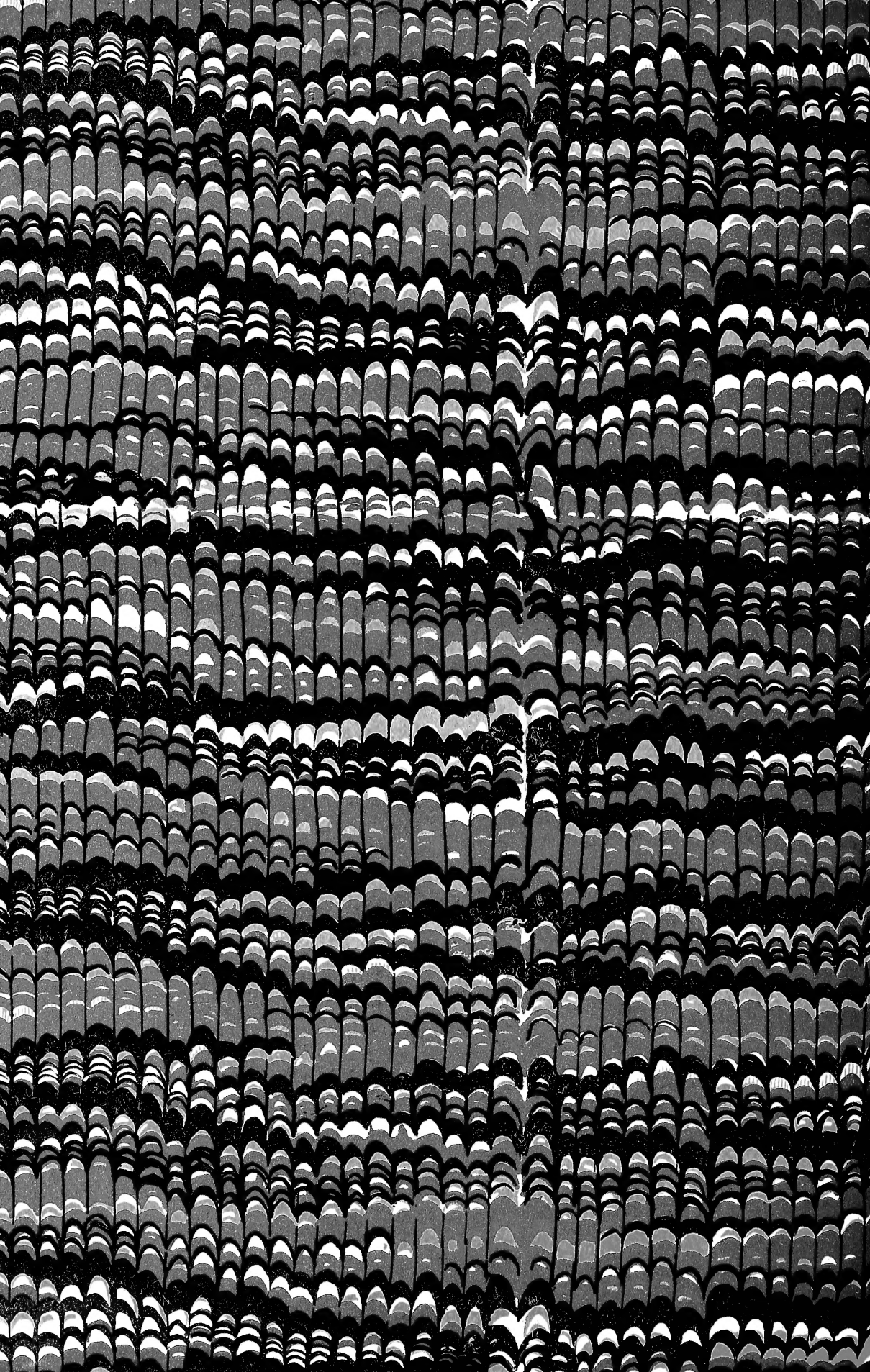


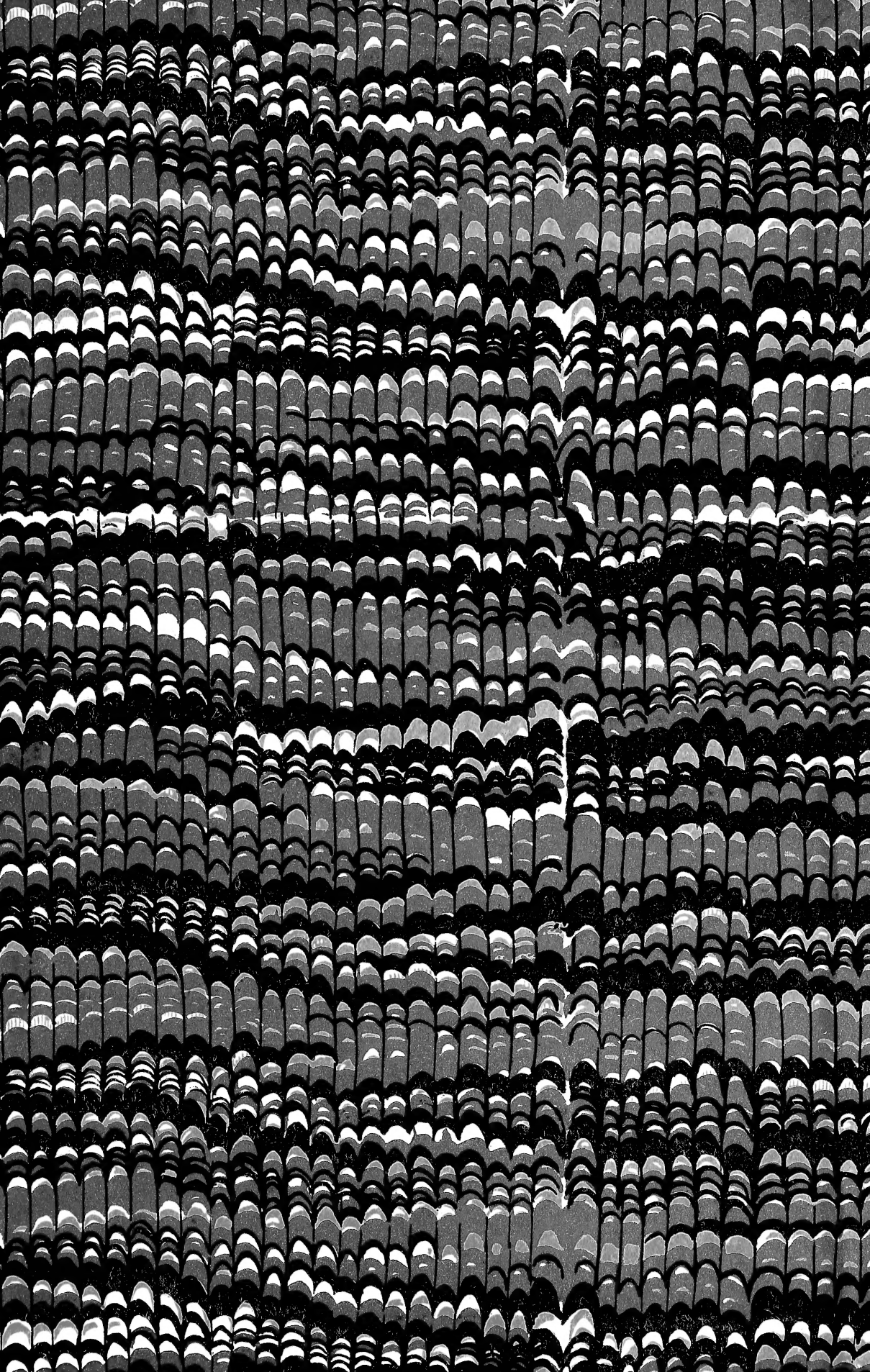












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